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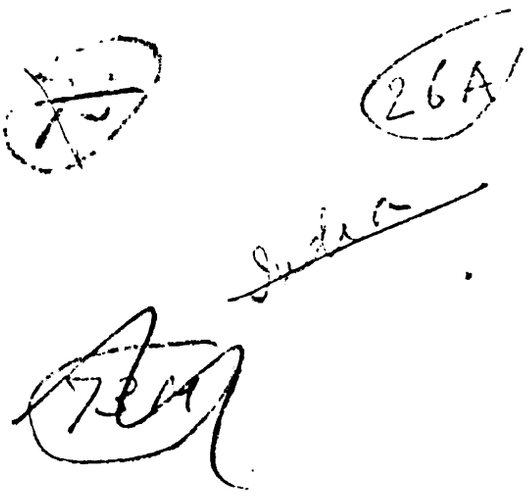

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REPORT ON THE
SARDAH CANAL PROJECT.

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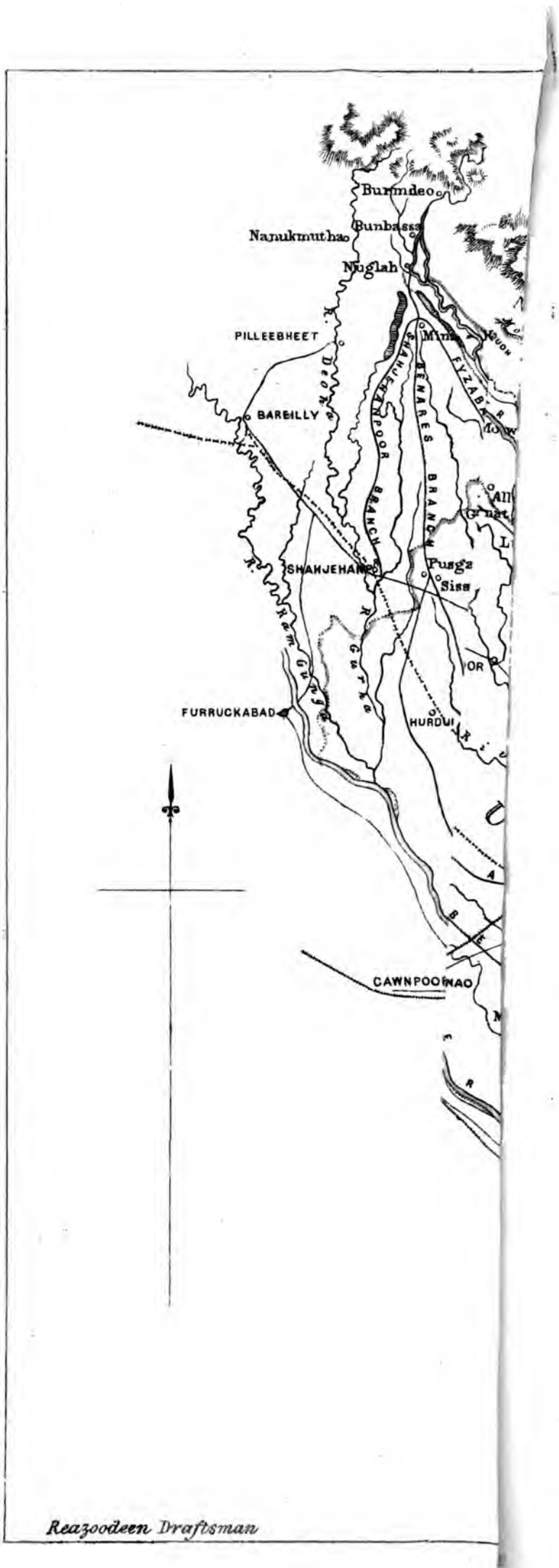
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REPORT

ON THE

SARDAH CANAL PROJECT,

BY

CAPTAIN J. G. FORBES, R. E.,

Officiating Superintending Engineer, Sardah Canal.

LUCKNOW:

PRINTED AT THE OUDH GOVERNMENT PRESS.

1871.

No. 285 of 1870-71.

FROM

THE SUPERINTENDING ENGINEER,

SARDAH CANAL, OUDH.

To

THE CHIEF ENGINEER,

DEPARTMENT PUBLIC WORKS, OUDH, LUCKNOW.

Lucknow, September 1st 1870.

SIR,

With reference to my letter No. 189, dated 22nd June 1870, stating that the project for the Sardah Canal would be ready for submission on 1st September 1870, I have the honour to forward the report on the Proposed Canal together with :—

12 Appendices as per list on Page IV of report.
8 Volumes, Estimates of Masonry Works on Canal.
8 „ „ Earthwork.
5 Maps as per list on Page V of report.
43 Drawings of Masonry Works, &c. Page VI.
61 Plans and Sections of proposed Canals. Page VII.

I have the honour to be,

Sir,

Your most obedient servant,

J. G. FORBES, CAPTAIN, R. E.,

Offg. Superintending Engineer,

Sardah Canal, Oudh.

SARDAH CANAL.

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Report on the Sardah Canal Project by Captain J. G. Forbes, R. E., Officiating Superintending Engineer.

SECTION I.

Introduction.

Area to be irrigated.

1. The tract of country to be provided with irrigation (*vide* paras. 1 and 3 of General Report) contains an area of upwards of 20,000 square miles; extending from Burm Deo, at the foot of the Himalayas, to Beyreah, at the junction of the rivers Gogra and Ganges. It is bounded on one side by the rivers Gurha or Deoha* and Ganges; and on the other by the Gogra.—*Vide* Map No. 1 of the Gogra-Ganges Doab. Scale—8 miles = 1 inch.

Height of river Sardah above the sea.

2. At Burm Deo, 846 feet above mean sea level,† the river Sardah, after a course of 200 miles, issues out of the hills, and running in a south-easterly direction a distance of more than 100 miles, separates into two branches; the main one falling into the Gogra, 30 miles further on, at Mullapore; and the second or smaller branch, which in ordinary seasons is dry at its head, joining the same river at Byramghát, 45 miles below Mullapore, where the reduced level of water surface is 336 feet, or 510 feet below the Sardah at Burm Deo.

Rivers Goomtee and Sye.

3. The Doab, or country between the Gogra and Ganges, is divided into three minor Doabs, by the small rivers Goomtee and Sye; the former having its sources at Mina Kote, 630 feet above mean sea level, but not appearing as a distinct stream until it arrives near Madho Tandah, 610 feet above the sea; and the latter rising at Sissoree, (a small village 12 miles east of Shahjehanpore,) 499 feet above sea level. After running nearly 300 miles, this stream falls into the Goomtee, below Jaunpore, at a level of 214 feet above the sea; the combined rivers then flow on for 25 miles, and fall into the Ganges about 17 miles north-east of Benares, the reduced level of water surface at junction being 192 feet above mean sea level.

Gogra-Goomtee Doab.

4. The watershed of the Doab, (292 miles in length by 18 miles in breadth,) between the Gogra and Goomtee, runs from Mina Kote‡ to Fyzabad, 200 miles, and from thence to Azimghur, a further distance of 85 miles. The fall in the country is considerable, especially in the upper portion; from Burm Deo to Bunbassa, 9 miles, the slope is 12½ feet per mile, or 1 in 422; and from Bunbassa to Mina Kote, 21 miles, it is 6 feet or 1 in 880. Mina Kote is, as already stated, 630 feet above sea level; 30 miles below Mina Kote, at Seramow, the reduced level is 556 or 74 feet lower, giving a slope of nearly 2½ feet per mile (1 in 2115.) 40 miles

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* Called Deoha, above Shahjehanpore and Gurha, below it.

† The figures marked on plans and sections forwarded with General Report last year, were referred to Lieutenant Anderson's datum at Burm Deo, *vide* para. 7 of General Report: connection having now been made with the Great Trigonometical Surveys Series, the levels in present report and plans are all referred to the G. T. S. datum, *viz.*, mean sea level at Kurrachee Harbour.

The levels on former plans and sections, if deducted from the constant 958·94 will show heights above mean sea level.

‡ In Para. 8 of General Report, it was erroneously stated that Soorae, 12 miles above Mina Kote, was at the head of the watershed. But surveys and levels executed last year, show that the old maps (made in 1834-36) are incorrect, and that the Mala swamp does not drain into the Kunhout nuddee, but direct into the river Gurha, what is shown in the old maps as a drainage channel, is actually an artificial watercourse, excavated many years ago to supply water for the irrigation of the low land at the head of the Kunhout,

below, at Lukheempore, the ground is 484, the slope in this distance then is reduced to 1·80 feet per mile (or 1 in 2,933). At Uncha Khera, 17 miles lower down, (the head of the watersheds between the Gogra, Kullianee, and Goomtee,) the reduced level is 453 or still 1·80 per mile. Below Uncha Khera the slope decreases, for at Ghyla, 23 miles lower, the reduced level of ground is 424, or at the rate of 1·26 only per mile or 1 in 4,190. This slope continues from Ghyla to Rudowlee, 65 miles (the head of the watersheds between the Gogra, Tonse, and Goomtee), where the reduced level is 340. From here to Azimgurh, 110 miles, where the reduced level of the country is 247, the fall is still further reduced to ·84 per mile, or 1 in 6,285.

Goomtee-Ganges Doab.

5. The watershed of the main Doab (360 miles by 12 miles), between the Goomtee and Ganges, runs from Mina Kote to Sissoree, (above the source of the river Sye) 55 miles. The slope in this distance being nearly 2½ feet a mile, (1 in 2,115) or the same as the first thirty miles in the Gogra-Goomtee Doab. From Sissoree to Madhoganj, 55 miles, where the reduced level is 446, the slope is nearly one foot a mile (1 in 5,280) and from Madhoganj to Morawun, reduced level 387, distance 75 miles, the fall is reduced to ·74 per mile (1 in 7,135) which slope is increased to ·78 per mile (1 in 6,769) to Benares, 180 miles lower down the Doab, where the reduced level is 253.

Goomtee-Sye Doab.

6. The Doab between the Goomtee and Sye is 247 miles in length, with an average breadth of about 18 miles. Commencing at Sissoree, with a reduced level of 499, it runs for 57 miles with a slope of about a foot per mile (1 in 5,280) to Balamow, where the ground is 434 feet above the sea. From thence to Surthooa, (8 miles south-east of Lucknow) 53 miles, reduced level 395, with a fall of ·74 per mile (1 in 7,135); and from Surthooa to Jaunpore reduced level 276, distance 137 miles, the slope, as in the Sye-Ganges Doab, is increased slightly to ·78 per mile or 1 in 6,769.

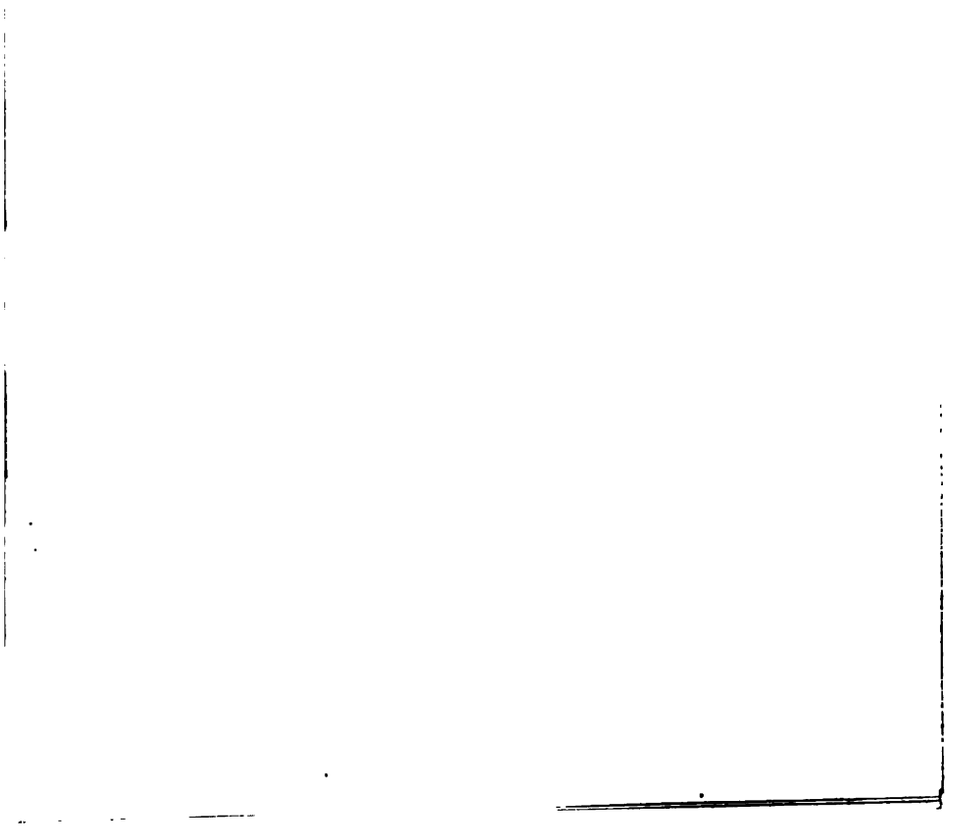
Water surface levels of river.

7. Having thus glanced at the relative heights along the different watersheds of the Gogra-Ganges Doab, if we examine the levels of the water surface in these two rivers, or in the Goomtee and Sye, we find that on cross sections taken perpendicular to the watersheds, these streams are everywhere from 30 to 70 feet below the high land on either side of them.

River Sardah and Koreallie or Gogra.

7A. For taking first the Sardah and Koreallie or Gogra* (*vide* also section on opposite page), we see that between Goosree and Moondeea Ghâts, 8 miles east of Mina Kote, the river is 58 feet below the point where irrigation is required to commence. Opposite Seramow, it is 52 feet below the ground. Near Gola Gokarnath, it is 35 feet below the surface of the country, and carrying on the section to the Koreallie, where it issues out of Nepal, we find the river at that point to be 18 feet *lower* than the Sardah, or 53 feet below the watershed. At Mullapore, the junction of the Sardah and Koreallie, this depth has increased to 70 feet. At Byramghât it is 52 feet below the surface, and at Fyzabad, 30 feet.

* This river is called the Koreallie in the upper part of its course; after its junction with the Girwa and Sardah, it is called the Gogra.



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River Ganges.

8. Looking now at the Ganges, we find that on the watershed, opposite to Futtehgurh, the country is 70 feet above the river; opposite Cawnpore it is 45 feet; near Allahabad, 66 feet; and at Benares 58 feet.

River Goomtee.

9. The Goomtee runs in a like depressed channel, for near Hurdui the river is 51 feet below the surface; at Lucknow it is 66 feet below the watershed, near Alum Bágh; at Amghát it is still 66 feet below the country; at Sultanpoor, 61 feet; at Jaunpore, 51 feet; and at its junction with the Ganges, 55 feet.

River Sye.

10. Similarly, the Sye at Hurdui, is 30 feet below the country; at Ajgaen it is still 30 feet lower than the level of the ground; and this depth increases to Pertabgurh, where the river is 60 feet below the washed.

Scheme of Canal as proposed in General Report of 1869.

11. A scheme for a proposed canal to irrigate the high plateaus existing between each of these rivers, was sketched out in the General Report, submitted last year. Briefly stated, the project was to lead out a canal from the Sardah at Nuglah or Kunjah Bojh (18 miles below Burm Deo) which in 14 miles would run to the surface of the country at Mina Kote, where the canal was to divide into two branches, following the course of the high ground in each of the Doabs; the right, or Benares branch running down the watershed of the country to Benares, throwing out a smaller branch to Lucknow and Jaunpore at Sissoree, the head of the watersheds between the Goomtee, Sye, and Ganges.

The left or Fyzabad branch was intended only to supply water to the country as far as Uncha Khera, at which place a supplementary channel from the Sardah, or Koreallie would join it, and running down the country between the Gogra and Goomtee, would irrigate the Fyzabad, Azimgurh, and Ghazeepore districts.

Rotation system unavoidable.

12. The amount of water in the river Sardah, during the months of minimum supply, from January to April, was not sufficient, however, to irrigate the Doab between the Goomtee and Ganges without adopting the "Tahteel" or rotation system in the Benares, Lucknow and Jaunpore branches respectively. This method, although in use on other canals is avowedly an objectionable one, and would not have been advocated had there been any other more economical mode of supplying the irrigation required. It will be seen, however, that in the present project, it is only in extraordinary years, when the supply in the river falls abnormally low, that recourse will have to be made to the rotation system.

SECTION II.

Sources of Supply.

13. Sources of supply other than the Sardah had of course been examined, but could only be cursorily alluded to in the former report (paras. 23—26,) as the surveys had not then been completed. These having now been finished, it is possible to answer the questions contained in the instructions in Secretary to Chief Commissioner, Oudh, Depart-

ment Public Works, letter No. 3876, dated 21st March 1870, regarding :—

1. "Investigation of supply from the Koreallie, its difficulty and expense."

2. "Examination of Goomtee and Sye, to see if high land can be found at any point suitable for a crossing, and thus to save the cost of heavy embankments and expensive aqueducts across those rivers."

3. "Examination of site at Byramghát, with the view to a weir being constructed there on the kunkur shoals at a reduced cost."

4. "Careful enquiry into the feasibility of conveying a supply from Byramghát across the Goomtee, in order to irrigate the Goomtee-Ganges Doab."

It is easy to see from the accompanying map (on 8 miles to an inch scale) of the Gogra-Ganges Doab, the relative levels of the rivers, and the ground that can consequently be irrigated; and thus to deduce whether it is possible to utilize any other river in conjunction with the Sardah, so that the rotation system may be avoided.

Discharges of rivers in Oudh.

14. The cold weather, or lowest discharges in average years of the rivers in Oudh are as follows :—

Koreallie,	11,000	cubic feet per second, at Ramnuggur, where it issues out of Nepalese Territory.
Sardah,	5,500	cubic feet at Bunbasa.
Gogra,	18,000	cubic feet at Byramghát.
Ganges,	5,000	cubic feet at Cawnpore.
Goomtee,	500	cubic feet at Lucknow.
Sye,	30	cubic feet at Pertabgurh.

In the North-Western Provinces, the river Gurha, below the junction of the Kunhout Nuddee, at Shahjehanpore, has a discharge of 225 cubic feet.

Height of river Koreallie, above mean sea level.

15. Naturally, the Koreallie, with its minimum supply of 11,000 cubic feet per second, would be the first river examined to see if it is feasible to take out a canal from it for the irrigation of the lower part of Oudh, and Azimgurh; and possible, by an aqueduct across the Goomtee, to the Benares and Jaunpore Districts.

Referring to the map, however, it will be seen, that at Ramnuggur (about 10 miles from the foot of the hills) the river is only 449 feet above mean sea level. The section opposite para. 7 A, also shows that the Sardah, which runs adjoining to the Koreallie on the west, is everywhere considerably higher than the latter river.

Channel from Ramnuggur on the Koreallie.

16. Supposing a channel taken out on a slope of only one foot in five miles (or 1 in 26,400) from the Koreallie at Ramnuggur, it would have to run nearly due south to Chuknathpore in order to cross the Sardah on the same level; from thence, allowing the same slope of bed to the canal, the water in the channel would not run to the surface until it arrived at Ghyla (70 miles from Ramnuggur), below which point the whole of the Doab between the Gogra and Goomtee would be commanded. Map No. 3 and Section No. 59 show clearly the nature of the ground to be traversed between Ramnuggur and Ghyla.

Irrigation of Goomtee Doab from Ramnuggur Channel.

17. We have now to consider how the water can be taken to the Goomtee-Sye Doab. At Ghyla, the country is 424 feet above mean sea level and the bed of the canal would be 417. The best position, then, for the Goomtee-Sye Canal to cross the Goomtee would probably be near Mungooan (21 miles from Ghyla), below the junction of the Suraen Nuddee (where the reduced level of water surface in the cold weather is 364, or 53 feet below bed of canal at Ghyla), for, say that the bed of the aqueduct over the river is kept 30 feet above water surface so as to admit of moderate digging in the high land (which it must be recollected is everywhere from 50 to 60 feet higher than the river Goomtee), and not very excessive embankment in the Khadir; that two 10 feet falls are made between Ghyla and Mungooan, and that the remaining 2 feet is lost in slope of canal, we arrive on right bank of Goomtee with a reduced level of 394 for bed of canal, and crossing the Beyta Nuddee, above Kakoree, the water will run out to the surface a few miles south of the Cantonments of Lucknow; from whence a line to Morawun, will lead the water of the Koreallie to the watershed of the Sye-Ganges Doab.

Cost of Ramnuggur Channel.

18. The length of this canal from Ramnuggur to Morawun would be 145 miles, *viz.*, 70 from Ramnuggur to Ghyla; 55, Ghyla to Lucknow; and 20, Lucknow to Morawun. The cost of the canal channel alone, may be estimated a £5,000 per mile, from Ghyla to Lucknow, and £3,000 per mile from Lucknow to Morawun; the probable expenditure on this account then would be—

£685,000	to which amount would have to be added—
£455,000	*for the weir across the Koreallie,
£120,000	for the Sardah dam,
£40,000	for the Goomtee aqueduct,
£15,000	for the Beyta and Sye aqueduct, or a grand total of
	£1,315,000

Disadvantages of Ramnuggur Cannel.

19. Putting aside the obvious disadvantages entailed in the execution of a canal across the low lying valley of the Gogra, intersected as it is with innumerable streams and swamps; the unadvisability of leading water across land, where the level of springs is already within 2 to 10 feet from surface; and the imprudence of constructing a channel in the high land crossing all the natural drainages which supply jheels and tanks from which there is already existing irrigation, the stoppage or diversion of which drainages will be keenly resented by landowners, and the interference with which irrigation will create considerable changes in the revenue settlements of the districts traversed by the possible Ramnuggur line; the fact of its costing upwards of a million and a quarter sterling merely to *bring* water to the surface for the supply of only half the country in the Gogra-Gangetic Doab (*vide* para. 20), would tend to show that a canal in this direction could not be made with any advantage to the country.

* The estimate for the weir and head works across the river Ganges at Rájghát, where the river is smaller than the Koreallie at Ramnuggur, amounted to £100 per running foot.—*Vide* Ganges Canal Committee's Report, Appendix F. Estimate No. 8. Page XXVIII.

Land irrigated from the Ramnuggur Channel.

20. Some prominence, however, has been given to this scheme in order to impress upon the mind that with a canal led out from the Koreallie at the *highest* spot from which it is possible to lead it out, the irrigation from it can only commence to the east of a line drawn due south from Ramnuggur on the Koreallie, to the Ganges at Dalamow; and that to the left of this line, where it must be borne in mind, water is more urgently required than in the lower part of the Doab (*vide* para. 1 of General Report) the irrigation must be provided from some source other than the Koreallie.

Mullapore Channel.

21. The above scheme being inexpedient to adopt, Mullapore, at the junction of a branch of the Sardah with the Gogra, might be considered as a possible favourable site for the head of a canal; for by damming off the second or right branch of the Sardah (which joins the Gogra at Byramghát) we avoid the necessity of crossing that river, and will thus save some expense; although, by fixing the canal head lower down the Gogra, the cost of the weir across the river will be increased; and we lose a considerable amount of irrigation which could have been provided from the Ramnuggur line.

Mullapore is 375 feet above mean sea level, or 74 feet below Ramnuggur. Taking out a canal from here we run to the surface in the Gogra-Gomtee Doab at Tikaetnuggur, a few miles north of Durriabad. The bed of the canal at Tikaetnuggur being 353, allowing two 10 feet falls, we cross the Goomtee north of Inhona by an aqueduct 30 feet above water surface level, and arrive on the Goomtee-Sye Doab at Burna, 23 miles west of Sultanpoor, with a reduced level of bed of 325.

Crossing the Sye-Nuddee south of Amethee, the Sye-Ganges Doab is gained a few miles west of Soraon; or in other words, a line drawn from Mullapore on the Gogra to the Ganges at Allahabad will show the extreme western limit of irrigation that can be derived from the Mullapore line.

Cost of Mullapore Channel.

22. On the face of it, it is evident that the making of such a line would involve too great an expense for the comparatively small area of irrigation that could be derived from it; but to remove all doubts, let us see the probable cost of this line. Putting the Gogra weir at £530,000, culverts and drainage works in the Khadir £50,000, aqueducts over Kulleanie, Goomtee, and Sye rivers £60,000, canal channel from Mullapore to Burna (110 miles at £5,000 per mile) £550,000, and from Burna to Soraon (55 miles at £3,000 per mile) £165,000, we have a grand total of £1,355,000 or £40,000 more than the cost of the Ramnuggur line.

Project by Sir Arthur Cotton and Colonel Rundall, for the irrigation of Oudh.

23. Appendix A gives a description of the project by Sir Arthur Cotton and Colonel Rundall for the irrigation of Oudh.

It will be observed that "Main Trunk Canal No. 3 from Mullapore," is intended to cross the Goomtee north of Lucknow. The levels on the map show the impracticability of the scheme.

Byramghát Channel and cost.

24. We have next to consider the possibility of taking out a canal from Byramghát, where the cold weather water surface in the river Gogra

is 336 feet above mean sea level. A channel from which point would reach the Gogra-Goomtee Doab a few miles south east of Rudowlie with a reduced level of bed of 320, and allowing for one 10 feet fall, would cross the Goomtee north of Dadruh, and the Sye west of Pertabgurh, arriving on the watershed of the Sye-Ganges Doab west of Phoolpore, but the area of irrigation that could be commanded would barely exceed 2,000 square miles, and the cost of the channel simply to bring water to this tract would again be upwards of a million sterling.

Viz.	Weir at Byramghát	£562,000
	Aqueducts for Goomtee and Sye	60,000
	Drainage works, ...	£10,000
	Canal channel 70 miles at £5,000 per mile,	£350,000
	Ditto 50 miles £3,000 per mile ...	£150,000
	Total, ...	£1,132,000

Kunkur shoals at Byramghát.

25. Attention has been drawn to the circumstance that, in consequence of the existence of kunkur shoals at Byramghát, a weir might possibly be built there at less cost, than anywhere else on the Gogra, but a very slight consideration, when the true state of the case is known, will show, that instead of the kunkur shoals reducing the cost, they will increase it. Kunkur shoals do exist, but they are in small isolated patches a few square yards in extent, and are nowhere more than 3 to 4 feet in depth. Borings show that to a depth of 30 feet, below which depth it was not considered necessary to bore, nothing but pure sand is met with.

Even allowing that a kunkur shoal existed across the whole width of the stream, it would be impracticable to build a weir on a reef only 4 feet thick, overlying pure sand which extends to an unknown depth.

Nature of action on foundation of weir.

26. The Ganges Canal Committee, when reporting on the design for weirs across the Ganges, which has a cold weather discharge of about one *fourth* of the Gogra at Byramghát, pointed out that the foundations would have to be secured against two distinct forces.

1st. "The scouring action which is produced when the stream "meets with an obstruction, and which would undermine and destroy the "foundations, unless they are carried down to the full depth to which "the scouring extends, or unless they are protected by a mass of stone "or other suitable material."

2nd. "The pressure arising from the water on the up-stream side "of the weir being ponded up above the level of the water on the down-"stream side; for unless the pressure is counteracted by the formation "of the foundation wells, or filling between them, into a water tight "screen, it will force the water through, and by carrying with it the sand "under the body of the work would cause it to subside and fall to "pieces."

Impracticability of building a weir on kunkur shoals.

27. This being the nature of the action to which the foundation would be subjected, it is evident that the weir cannot be built on the

kunkur shoals, but must be founded on wells ; and the cost of sinking these, through the kunkur reefs, would, of course, be considerably more than if they were carried down in pure sand only.

That a permanent structure cannot be maintained on such shallow kunkur shoals as those at Byramghát, has been practically proved ; for three years ago a circular masonry pier, 90 feet in diameter, was built on a reef extending out from the left bank of the river, which was intended to act as the permanent head for the Byramghát and Baraich road. The very first flood that came down, however, carried away both permanent head and kunkur shoal, not a vestige of either remaining ; and where they *did* exist the river is now 30 feet deep.

Changes in the course of the Gogra at Byramghát.

28. The sketch (compiled from maps supplied by Executive Engineer, 2nd Oudh Road Division) on opposite page, showing the changes in the course of the Gogra, will prove that Byramghát is not a favourable site for a weir. The stream of the river, on a length of upwards of a mile and a half north of Byrampore, has shifted completely over to the east, and encroached on the land half a mile within its old bank of 1863 ; this action is still going on, and a weir below the confluence of the Chowka or Sardah, where only it could be placed, would therefore be liable to have its left flank turned ; for without going to an enormous expense, and even then the result would be doubtful, no amount of protecting works could for any length of time retain, in its desired channel, a river like the Gogra, running as it does between banks of pure sand, which are constantly being eroded, and where no dependence can be placed on the stream remaining in one channel even for a few weeks at a time.*

Unadvisability of constructing the Byramghát channel.

29. The above facts, together with the cost of the channel, would demonstrate the unadvisability of constructing a canal from Byramghát ; lower than which point, it is evident from the levels of the river, it is not advantageous to take out a canal from the Gogra, for the very limited area which would come under its operation.

Abandonment of Koreallie, or Gogra, as a source of supply.

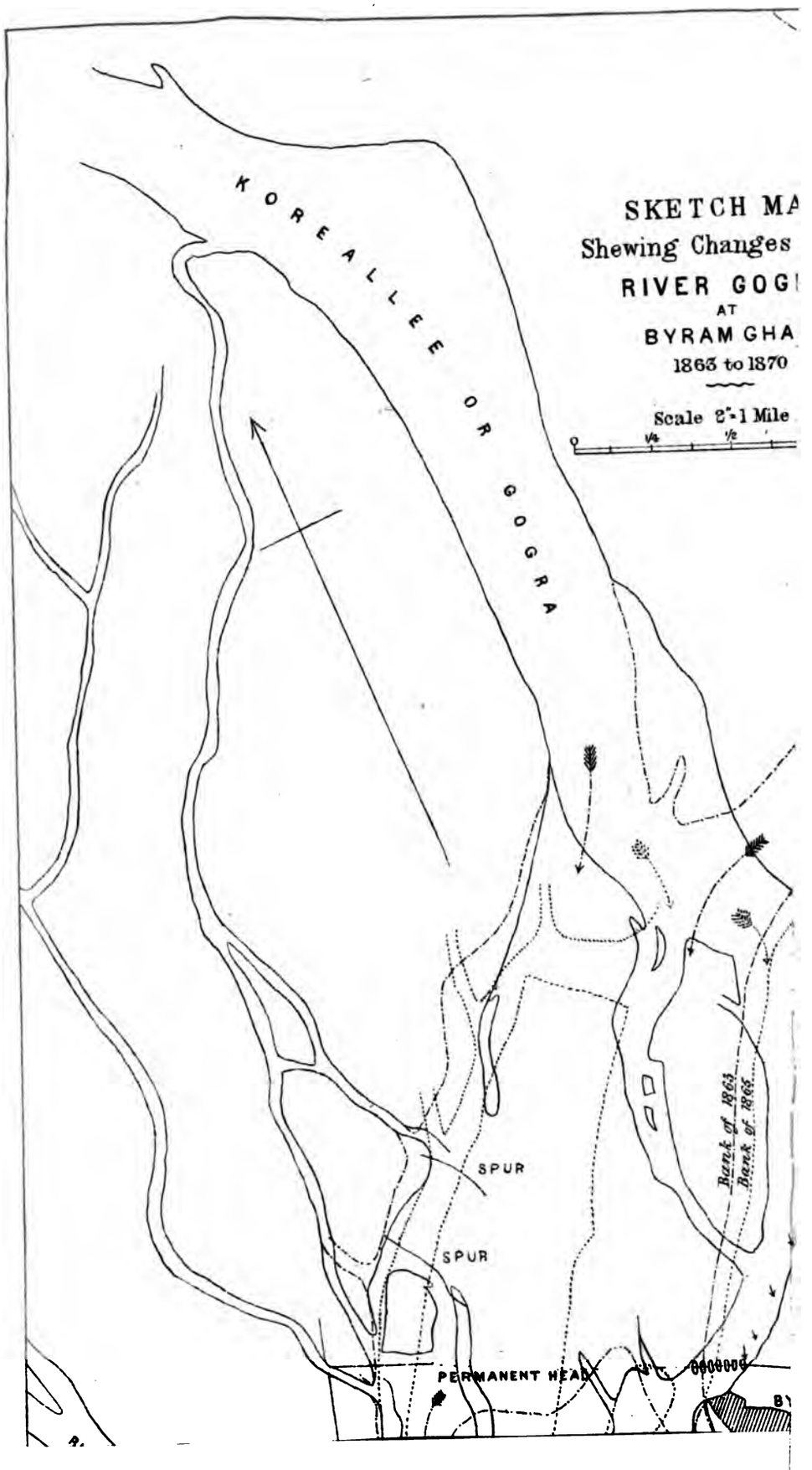
30. Unwillingly then, we must abandon the idea of leading a canal from this magnificent stream, and, turning to the Ganges, must seek for some position from whence it may perhaps be possible to irrigate the Goomtee-Ganges Doab ; but here again the peculiar configuration of the country confronts us with special difficulties entailing considerable expense in the execution of any scheme from this river ; for at Futtehghur, above the junction of the Ram Gunga, the level of the water is only 396 feet above the sea, and supposing a canal taken out from here with a slope of one foot in five miles (1 in 26,400) it would not commence irrigating for upwards of a 100 miles, or until it arrived at Morawun.

Channel from the Ganges at Futtehgurh.

Cost of Futtehghur Channel.

31. The cost of this scheme would again exceed one million pounds ; and for the greater part of its distance the channel would have to be taken along the Khadir, or low land of the Ganges, where water is everywhere met with within a few feet of the surface, and where consequently the introduction of a canal in embankment would deteriorate what is now good land, by raising the levels of springs to the surface of the ground. It is

* Since this was written, it is reported that a considerable portion of the left bank and of the village of Byrampore has been washed away.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evident, then, that Futtehghur is not a suitable place for the head works of a canal for the Goomtee-Ganges Doab.

32. At Cawnpore, the height of the river is 360 feet above sea level, and a channel, 80 miles in length, led out from there would run to the surface a few miles south east of Selon, and would afford irrigation to only 2,000 square miles of country.

A weir at Cawnpore, if built in conjunction with the railway bridge now building there, might perhaps be constructed at less cost than at Futtehghur; but yet, taking into account the numerous works that would have to be built for the passage of drainages in the Khadir, the lowest estimate for this line would be a million sterling, which sum provides only for the delivery of water on the surface at a spot about 35 miles north west of Allahabad.

Below Cawnpore, the levels show that there is no suitable position for a dam; and hence, the Ganges and Gogra both being unavailable as the sources of canals, at a reasonable cost, we must fall back, as already stated in paras. 23 to 28 of General Report, upon the only remaining river, *viz.*, the Sardah, from which it is possible to get a supply; for neither the Goomtee or Sye carry down a sufficient amount of water to be utilised with any profit.

Comparison of cost in bringing water to the surface of the country.

33. Now, instead of expending upwards of a million sterling in the construction of channels which merely lead the water to the surface of the ground for the irrigation *of less than half* the area comprised in the Gogra-Ganges Doab, and where at least three millions more must be spent in continuing the lines of canals down the different watersheds, we find by the detailed estimates attached to this Report that water can be led to the surface of the country at Mina Kote, the head of all the watersheds, for £759,000, a sum which includes the cost, not only of the main canal itself, but also of the escape, and of the regulating bridges at each of the heads of the branches, and when delivered at Mina Kote, the canal has command over the whole country.

34. It may perhaps, however, be considered that the expenditure of a million pounds on a channel from the Gogra or Ganges, will be more economical than the cost of taking a canal down the whole length of the watershed from Bunbassa to Morawun.

Turning to the estimates, however, we find that this line will cost £1,589,500;* the area that can be irrigated from it (not including khadir lands, &c.) is upwards of 2,300 square miles, or 1,427,000 acres, out of which amount, say that only 475,000 acres are annually irrigated at Rs. 2-8† per acre, or a return of £1,18,750; being at the rate of 7½ per cent. per annum, exclusive of miscellaneous dues for navigation, mills &c., *i. e.* we irrigate the whole country from Mina Kote to Morawun, get a gross return of 7½ per cent. on the outlay, and still have 1,762 cubic feet of water to spare (*vide* section No. 19 Benares Branch) for the irrigation of the country

* Cost from Bunbassa to Mina Kote £759,000, for which sum 6,300 cubic feet are delivered; of which 4,900 cubic feet are required for the Benares and Jaunpore branches. The proportionate cost therefore due to these branches is £590,500.

Cost from Mina Kote to Sissoree £750,000, of which £428,000 is on account of the Benares line, or a Total to Sissoree of £1,018,500.

Add cost from Sissoree to Morawun £571,000 and grand Total £1,589,500.

† On the Ganges and Jumna canals Rs. 4, per acre.

between Morawun and Benares; whereas, by the Gogra or Ganges channels a sum of nearly one million pounds will be absolutely sunk without any return, as this channel cannot irrigate until it arrives at Morawun; below which point the cost will of course be the same as that of the watershed line.

Rotation system not so disadvantageous on Sardah as on Ganges Canal.

35. True it is, that by this method, the whole of the Doab below Morawun will be furnished with a constant and steady amount of water, instead of the fluctuating supply entailed by the rotation system; but this gain will not compensate for the extra expenditure that will be involved, when we consider the nature of a great portion of the country, between Morawun and Benares, where 70 per cent. of the land is already watered (*vide* para. 39) and where, therefore, the disadvantage of lowering (not completely shutting off) the supply in the canal in alternate weeks for two or three months only in the year will not be felt as it is in the less favoured districts on the Etawah and Cawnpore Divisions of the Ganges Canal. From May until November there is always sufficient amount in the river to give full supply in all the branches of the canal; and, as will be seen further on, arrangements have been made for admitting 8,000 cubic feet into the head of the canal, instead of 7,000, as calculated, without endangering the safety of the works, so that should the periodical rains fail, tanks and jheels can still be filled from the canal.

Annual maintenance charges on direct River channels heavier than on watershed line.

36. In the same way, if a comparison is made between the cost of the Gogra or Ganges channels to either of the other Doabs, and the watershed line from Mina Kote; it will be found in each case that the result will be considerably in favour of the latter. It must also be recollected that the yearly repairs and cost of maintenance of a canal taken along the watersheds will be very much less than the annual expenditure on a channel carried in embankment across all the drainages in the khadir.

Subsidising supplies in the Rivers Goomtee and Sye.

37 In the remarks made by North Western Provinces Government on the General Report, allusion has been made to the possibility of subsidising the scanty supplies in the Goomtee and Sye, by supplementing them from the canal high up in their courses, and taking the water out again lower down; but running as these streams do in deep channels from 40 to 50 feet below the level of the country, it is evident that this will be a more expensive proceeding than leading a channel for 70 miles along the watershed of the country (*vide* para. 28 of General Report) for, in order to deliver the water into the river, a channel about ten miles in length with at least four masonry falls will have to be made; an expensive weir will then have to be built lower down the river, and even allowing that the present water surface can be raised 10 feet, a channel, *at least* 50 miles in length, the greater part of which will be in deep excavation, will have to be dug to recarry the water to the level of the country again.

Sardah Canal scheme preferable to any other.

38. Duly considering all the above facts, then, and bearing in mind that, with a channel from the Gogra or Ganges, the cost of irrigating the whole Doab will be upwards of 7½ millions, while the same object can be attained by the Sardah Canal for a little over 6 millions, it is evident that this latter is the more preferable project. Accordingly the plan and ar-

rangement for the distribution of water have been worked out in accordance with the original scheme, and the modifications pointed out by the Government of India.

SECTION III.

Sardah Canal.

A.—Distribution of Supply.

Irrigational requirements of Doab.

39. Of the gross area of about 20,000 square miles in the Gogra-Gangetic Doab, upwards of 3,500 square miles are included in khadir lands, &c., not requiring water, leaving a net area of 16,477 square miles to be irrigated (*vide* para. 41), but the districts traversed by the canal vary much, not only in soil and climate, but also in their need for water, for many are, in ordinary seasons, already extensively irrigated.

Turning to Appendix I, we find that the Shahjehanpore branch of the canal will pass through land, of which about 9 per cent. is already irrigated; the Benares branch to Sissoree, and the Fyzabad branch to Uncha Khera run through ground of an excessively sandy nature, where water is quite as much in demand as on the Shahjehanpore branch, the percentage of ground already irrigated being about 9 per cent. in the upper portion, and 5 in the Kheree district (13 per cent. on cultivation). Following the Benares branch down its course from Sissoree to Soraon, we find it runs through the Hurdui district which has 32 per cent. of its cultivated area irrigated from jheels, tanks, &c., (18 on gross area) then through Oonao, with 45 per cent. of cultivated area irrigated, (or 21 per cent. gross area), through Roy Bareilly, with 73 per cent. cultivated area irrigated (and 36 per cent. of gross area) and finally through Pertabgurh, which has an irrigated area of 74 per cent. of cultivated area, (or 26 on gross area.)

It is evident, therefore, that the same amount of irrigation is not required in this part of the branch as on the upper portion, and on the Fyzabad and Shahjehanpore branches.

The Lucknow and Jaunpore branch also runs through districts which are as well watered as the above, for it passes through Hurdui, with its 32 per cent. of already irrigated area (18 on gross area) through Lucknow with 45 per cent. of cultivated area irrigated, (21 per cent. gross area) and through Sultanpoor with 78 per cent. of cultivated area irrigated, (or 37 per cent. on gross area.)

The Fyzabad Branch, below Uncha Khera, will pass through Seetapoor, with 21 per cent. of cultivated irrigated area (12 per cent. gross area), then through Barabunkee, where 28 per cent. of cultivated area is already irrigated, (18 per cent. gross) and on through Fyzabad, where 57 per cent. of cultivated area is irrigated, or 31 per cent. of gross area.

Beyond Oudh, the canals are carried into the districts of Benares, Jaunpore, Azimgurh, and Gazeepore, where irrigation is much required, but the actual percentage of irrigated cultivated land, cannot here be given, as accurate statistics have not yet been prepared.

Estimated expenditure of water per square mile of gross area on various canals.

40. On the Ganges Canal, the expenditure of water per lineal mile of canal was taken at 8 cubic feet—which is equivalent to 1 foot per square mile of gross area, if the canal irrigates 4 miles on either side; to ·80 cubic feet if it irrigates 5 miles, and to ·70 if irrigating 6 miles.

On the Baree Doab and Sutlej Canals, the above allowance was given to some of the branches, but was reduced to an estimated expenditure of 6 feet per lineal mile on some of the minor branches, which would be equal to a consumption of ·75 cubic feet, ·60 cubic feet, and ·52 cubic feet, according as the canal is supposed to irrigate 4, 5, or 6 miles on either side.

On the Soane Canals an average allowance of ·75 cubic feet per square mile of gross area was made.

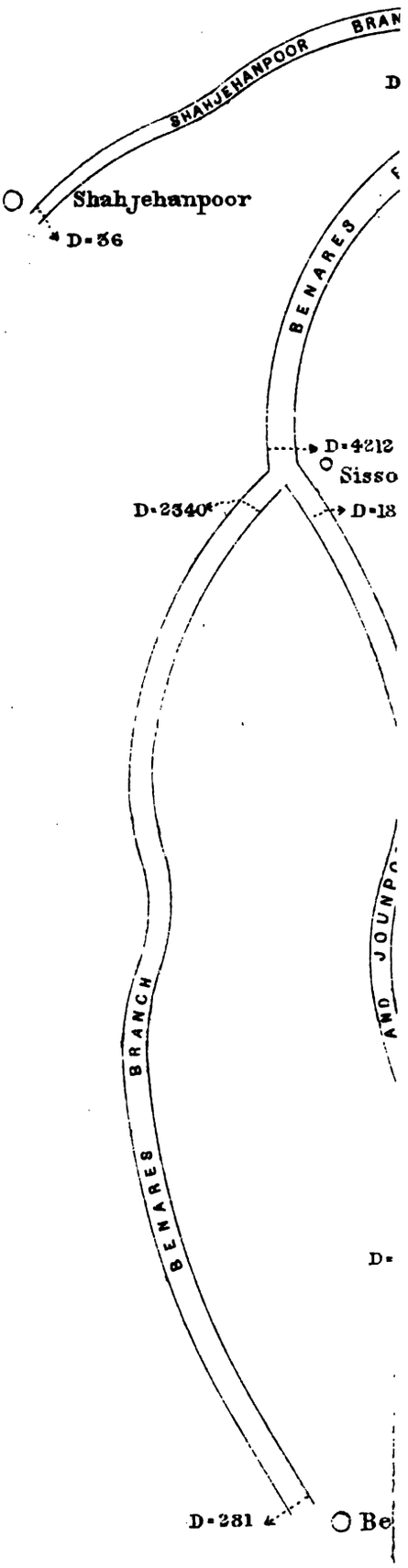
Estimated expenditure of water per square mile of gross area on Sardah Canal.

41. In the proposed scheme for the Sardah Canal, varying quantities (depending upon the nature of soil, the width of Doab, rain fall, (*vide* Appendix H.) and the irrigational requirements of the Districts,) have been allowed for the expenditure on each of the branches, as will be seen in the following statement :—

Name of branch.	Gross area in acres.	Gross area in square miles.	Discharge cubic feet per second.	Cubic feet of water per sq. mile.	Probable number of acres that will annually be irrigated.	Percentage on gross area.
Shahjehanpore, ...	272,640	426	351	·82	87,750	32
Benares from Mina Kote to Sissoree, ...	597,760	934	682	·73	170,500	28
Ditto from Sissoree to Soraon, ...	2,235,520	3,493	941	·28	235,250	10
Ditto from Soraon to Benares, ...	1,427,200	2,230	1,399	·63	349,750	24
Lucknow and Jaunpore, ...	2,288,000	3,575	1,823	·51	455,750	19
Fyzabad from Mina Kote to Uncha Khera, ...	883,200	1,380	1,065	·77	266,250	30
Lucknow, ...	577,280	902	616	·67	154,000	26
Fyzabad from Uncha Khera to Durriabad, ...	296,960	464	347	·74	86,750	29
Ditto from Durriabad to Fyzabad, ...	364,800	570	373	·65	93,250	25
Durriabad and Jaunpore to Gazeepore, ...	981,120	1,533	1,236	·80	309,000	31
Azimgurh, ...	620,800	970	706	·73	176,500	28
Total,... ...	10,545,280	16,477	9,539	·58	2,384,750	22

Possibility of increasing estimated allowance in extraordinary years.

42. It will be observed that the amount of water allowed per square mile of gross area varies from ·51 cubic feet on the Lucknow and Jaunpore Branch, to ·82 cubic feet on the Shahjehanpore, but in that portion of the Benares Branch which passes through the already well watered districts of Oonao, Roy Bareilly, and Pertabgurh, the allowance is reduced to ·28



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sufficient to provide the full amount required for each of the branches of the canal; and this supply can always be maintained until the beginning of November; thus the first watering, for both the kharíf and rabí crops, will be secured. In extraordinary years, full supply cannot be turned down the canal until the end of May, when water will still be in urgent demand for the preparation of land for the "kharíf"; by the middle of June, 7,850 cubic feet per second, or about 1,000 cubic feet per second more than the requisite full supply at head of canal, will be passing down the river; and as more water will probably be needed during these dry seasons in order to replenish jheels and tanks, the capacity of the canal has been made sufficiently large to allow of this extra quantity being admitted.

Amount of water at Delaha.

48. The amount of water, 2,945 cubic feet, required at Delaha, has been fixed on the assumption that there will always be a minimum supply of 3,000 cubic feet per second there (*vide* para. 51). Experiments, however, have been made in order to ascertain the probable amount of water lost between Bunbassa and Delaha; but until the weir is actually built at the former place, the results attained can only be looked upon as merely speculative conjectures as to what *may* occur when the entire amount of water in the river is turned off into the canal at Bunbassa.

Loss between Burm Deo, and Bunbassa.

49. Between Burm Deo and Bunbassa, where the slope in the river is excessive (*vide* sections on page 5), there is an average loss of about 1,000 cubic feet per second.

From 3rd to 8th February, and again from 11th to 26th March 1866, the actual discharge passing Burm Deo, was 6,865 cubic feet per second; whilst at Bunbassa only 5,953 cubic feet passed down, thus showing a loss of 912 cubic feet per second, or, 13·3 per cent. of the discharge at Burm Deo. From 8th to 10th March 1868, the discharge at Burm Deo was 6,686 cubic feet. Whilst at Bunbassa, it was 5,572, or 1,114 cubic feet per second less, showing a loss of 16·6 per cent. of the amount at Burm Deo.

From 15th February to 16th March 1869, when the river was extraordinarily low and the levels of springs in the Bangar lands four to five feet lower than in ordinary seasons, the loss was 23·7 per cent. between Burm Deo and Bunbassa; the discharge at the former place being 4,747 cubic feet, and at the latter 3,619 cubic feet, or a loss of 1,128 cubic feet per second.

Loss between Bunbassa & Delaha.

50. From the discharges taken this year, between Bunbassa and Chuknathpore, (20 miles below Delaha), it appears that the volume in the river steadily decreases until it arrives about 20 miles below where the shingly bed ceases and the sand commences. At this point there is a slight increment which goes on increasing for about 40 miles, when the discharge is again diminished.

For instance, when the discharge at Bunbassa was 6,022 cubic feet per second; at Moondeea Ghát, 13 miles lower down, where the shingly bed ceases, the discharge was 5,448 cubic feet; at Chunpoora Ghát, 9 miles

lower, the supply was *5,162 cubic feet; and again, 7 miles lower, at Bylah, it was *5,124 cubic feet, or practically the same.

Below this point, however, there was an increase; for, at Mooteea Ghát, 6 miles below Bylah, the discharge was 5,502 cubic feet, of which only 40 cubic feet were due to affluents. At Narowsa Ghát, 8 miles lower, the discharge was 5,651 cubic feet; at Marowcha Ghát, 10 miles below Narowsa, the supply was 6,220 cubic feet; and at Pulwari Ghát, 5 miles below Marowcha, it had increased to 6,890 cubic feet; at Sirsee Ghát, 14 miles lower, and close to Delaha, the amount in the river had decreased again to 6,718 cubic feet. Two other discharges were also measured, at 10 and 30 miles below the above ghát, *viz.*, at Burragaon, and Chuknathpore, giving amounts of 5,581 and 5,592 cubic feet per second respectively; but when these were measured, the supply in the river at Bunbassa was 200 cubic feet per second, less than when the above discharges were taken. Deducting this quantity, there still remains a loss of 1,000 cubic feet per second to account for in the distance of 30 miles between Sirsee Ghát and Chuknathpore; but looking at Map No. 3 it will be seen that below Sirsee Ghát the numerous nullahs on either side of the river drain away from it, instead of emptying themselves into it, as they do above the ghat; there are also many old and deserted beds of the river in close proximity to and below the level of the present stream; each of which, as well as the above nullahs are undoubtedly fed by percolation from the river, for although dry at their heads, they quickly become running channels, with a considerable amount of water passing down.

Minimum supply at Delaha.

51. Although it would be premature to come to any positive conclusion, based simply on the measurements of one year, as to the probable quantity of water that will be available at Delaha, yet the above discharges showing as they do, that when the river is at its lowest there are 800 cubic feet per second more at the site of the proposed head of the supplementary channel than at Bunbassa, 75 miles higher up, together with the facts †brought forward in the arguments used in discussing this question in the General Report, tend to prove that 3,000 cubic feet per second may *at least* be depended upon at Delaha.

C.—Velocities and Distribution of Water in Channels.

Distribution of supply at Mina Kote.

52. Assuming, then, that the required amounts at Nuglah, and Delaha are fixed at a proper standard, the distribution to the main branches at Mina Kote (the head of Irrigation) is made as follows, *viz.*, to

Shahjehanpore Branch,	...	...	351	cubic feet.
Benares „	...	...	4,894	„
Fyzabad „	...	...	1,349	„
Total at Mina Kote,			6,594	„

* * The discharge at Bunbassa was however only 5,875 cubic feet per second, on the date when these measurements where taken.

† *Vide* Para. 11, Secretary to Chief Commissioner, Oudh, Public Works Letter, No. 2750, dated 8th March 1869, Superintendent, Irrigation Works, Oudh, Letter No. 609, dated 27th March 1869, and Chief Engineer's Note on it.

Note by the Officiating Inspector General, Irrigation Works, on Sardah Canal Project, dated 9th June 1869. Para. 6, Government of India, Public Works, Letter No. 2699, dated 14th August 1869.

or 300 cubic feet per second less than the amount entering the canal at Nuglah, being the estimated loss (*vide* para. 56) between the above places; and with reference to para. 6 of Government of India, Public Works letter No. 269I, dated 14th August 1869, it may here be remarked that the data used in the General Report were based on the returns of the Ganges Canal, where the net volume at Roorkee, the head of irrigation, is compared with the irrigated area, and *not* the gross volume entering the head of canal at Hurdwar, between which place and Roorkee there is a loss of about 9 per cent. In accordance with the views expressed in above letter, no loss on account of evaporation and absorption has been allowed below Mina Kote; nor has it been deemed necessary to do so in the supplementary channel from Delaha to the head of its irrigating branch at Uncha Khera, as the water will be carried through comparatively stiff soil—totally different to the land between Nuglah and Mina Kote.

Velocity in upper section of canal between Nuglah and Mina Kote.

53. Turning now to the sections of the canal channel, we find that in order to admit the full amount of 6,935 cubic feet per second with a velocity *not exceeding 2 feet per second* and with side slopes of $1\frac{1}{2}$ to 1 and 12 feet depth of water, the slope must be 1 in 23,000, which gradient will also run the water out to the surface of country at Mina Kote.

Reasons for keeping velocity at less than 2 feet per second between Nuglah and Mina Kote.

54. In the General Report the calculations for this portion of the canal were based on the supposition that it would pass through soil which would stand a velocity of 2·75 feet per second; but since that report was forwarded, trial wells have been dug in order to ascertain the nature of the sub-stratum, which was found to be of the lightest and most sandy nature, worse even than the Toghulpore sand hills through which the Ganges Canal runs, and where it was observed that the bed used invariably to be eroded when the mean velocity was 2·5 feet per second. From experiments made on the Eastern Jumna Canal, by Major Brownlow, it appears that with soil of the description we have to deal with, the action of the stream was perfectly adjusted, when the mean velocity varied between 1·85 and 1·93 feet per second (*vide* Appendix D. of Colonel Crofton's report on the Ganges Canal). The velocity, in this section of the canal has therefore been based on the above fact, for with the slope of 1 in 23,000 and the following depths of water, the velocities will be as stated below :—

Depth of water.	Hyd. mean depth.	Mean velocity.	Discharge cubic feet per second.
12	11·047	1·972	6,935
11	10·041	1·894	6,074
10	9·323	1·812	5,255
9	8·445	1·724	4,478
8	7·556	1·631	3,745

should it be necessary, however, in extraordinary years to augment the supply of water in canal, the depth may be increased to 13 feet, when the discharge will be 7,835 cubic feet per second with a velocity of 2·05 per second.

Lowest velocity sufficient to prevent the growth of weeds in channel.

55. In the driest seasons, a supply of 3,745 may always be depended upon (*vide* para. 45), and the velocity of 1·631, due to it, is more than sufficient to prevent the growth of plants, &c., in the canal; for, from experiments on the Ganges Canal, it appears that in sandy soils weeds grow only in velocities under, or about 1·40 feet per second, although in one case, where there was clay, they grew in a velocity of 1·717.

Assumed loss by absorption, &c. between Nuglah and Mina Kote.

56. Now, on the Ganges Canal, in the first fifteen miles of its course, there is a loss of 9 per cent. by absorption, and evaporation (*vide* para. 14, page 14, Revenue Returns of Canals, North-Western Provinces for 1865-66). Assuming the same loss on the Sardah Canal, we should have a supply of only 6,310 cubic feet per second at Mina Kote, and if the width of canal bed was kept the same, 275 feet, as at Nuglah, the depth of water would be only 11 feet, whilst at Nuglah it would be 12, *i. e.*, the surface slope would be increased, and the velocity would exceed 2 feet, the limit of safety. With a bottom width of 249 feet, however, at Mina Kote, the depth of water will remain 12 feet and the mean velocity will be 1·965, or practically the same as that at the head, *viz.* 1·972.

However, as the bed of the Sardah Canal will in this portion of its course pass for a short distance below the ordinary level of springs, the whole of the above loss has not actually been taken, but only one-half, or 300 feet (*vide* para. 51), which, with a width of bed of 249 feet, will give a depth of 12·3 feet, a mean velocity of 1·98 and a discharge of 6,538 cubic feet, or within 60 cubic feet of the required amount at Mina Kote.

Varying widths of canal bed between Nuglah and Mina Kote.

57. Another advantage in gradually reducing the width of canal, between Nuglah and Mina Kote, will be the great saving of cost in the deep digging. The widths have therefore been calculated as follows:—

From Head	to	19,600	Feet	275 Feet
19,600	„	24,000	„	273 „
24,000	„	28,000	„	271 „
28,000	„	32,000	„	269 „
32,000	„	36,000	„	267 „
36,000	„	40,000	„	265 „
40,000	„	44,000	„	263 „
44,000	„	48,000	„	261 „
48,000	„	52,000	„	259 „
52,000	„	56,000	„	257 „
56,000	„	60,000	„	255 „
60,000	„	64,000	„	253 „
64,000	„	68,000	„	251 „
68,000	„	72,576	Mina Kote,	249 „

Width of canal bed, velocities, &c., below Mina Kote.

58. The diagram on page 13, together with the details shown on section sheets of the various branches, and Appendix (C) give the fullest particulars regarding the widths of channels, bottom, and mean velocities

and discharges of the several canals below Mina Kote. It is therefore only needful here to glance at the more salient points connected with the regimen of the bed in the different branches.

Shahjehanpore branch, velocities, &c.

59. It will be observed that the Shajehanpore branch, with its discharge of 351 cubic feet, has an allowance of 60 cubic feet per second for the irrigation of the country above the aqueduct over the old irrigation cut from the Mala Nuddee, and that the mean velocity of the stream has been kept at 1·97, the same as in the main canal. West of the Mala Nuddee, the soil is more clayey than on the east, and the velocity is consequently increased to 2·26 and 2·27, which, however, is again decreased to 1·90 and 1·84, as we approach the sandy tracts near Negohee, and finally to 1·62 per second at the tail of the branch, which is calculated to discharge 36 cubic feet per second, an amount which probably will be required for the town of Shahjehanpore.

Benares branch velocities.

60. The Benares branch, which is navigable in its entire length, starting with a calculated discharge of 4,894 cubic feet and a mean velocity of 1·94, is gradually increased to 2 and 2·04 per second, for a distance of 30 miles below Mina Kote, where the soil is of a better description, and again to 2·20 down to Sissoree, below which point we get into clayey ground capable of bearing 2·50 feet per second. As we go further down the Doab, however, this clay gradually merges into loam and pure sand, and the velocity is accordingly correspondingly reduced from 2·38 (18 miles below Sissoree) to 1·99 cubic feet at Benares, where the discharge is 281 cubic feet per second.

Velocities in Benares branch with extraordinary supply.

61. Should a greater supply ever be required in the Benares branch; by increasing the depth at its head about one foot, the velocity will still be below 2 feet per second at Mina Kote, and the discharge will be increased by 900 cubic feet per second ; below Mina Kote to Sissoree, the velocity will nowhere be more than 2·34, and at Sissoree 2·65, which the soil is easily capable of standing.

Velocities in Lucknow and Jaunpore branch.

62. The Lucknow and Jaunpore branch (also navigable), commencing at Sissoree, with a discharge of 1,823 cubic feet per second and a mean velocity of 2·36 cubic feet passes through ground of much the same character as that traversed by the Benares branch, and the velocity is accordingly gradually reduced from 2·36 at its head to 1·98 at its tail, at Jaunpore, where there is a calculated discharge of 358 cubic feet per second.

This branch also, as well as the Benares, can have its supply enlarged, by increasing the depth of water in the channel, without fear of unduly accelerating the velocity.

Velocities in Fyzabad branch from Mina Kote to Uncha Khera.

63. Reverting now to the Fyzabad branch from Mina Kote, the discharge of which is 1,349 cubic feet, as shown on diagram (of which 284 cubic feet per second is passed on to the other branches at Uncha Khera), it will be observed that the calculations for the channel have been worked out on the supposition that it is to be made capable of carrying down 1,765 cubic feet, or sufficient for the supply of the Lucknow branch, (*vide* para 41 of General Report) until the supplementary channel is completed.

Commencing with a mean velocity of 1·98 at Mina Kote, this is increased to 2·24 about 7 miles further on, and to 2·28 cubic feet per second at its tail at Uncha Khera, where there will be a calculated discharge of 1,016 cubic feet per second until the supplementary channel is made; after which, the discharge at Mina Kote will be 1,394, and at Uncha Khera 284 cubic feet, so as to keep up navigation with the lower branches. This discharge will give velocities of 1·85 at head, 2·05 at 7 miles below, and 1·54 at tail.

Supplementary channels velocity.

64. The supplementary channel from Delaha, which passes through stiff soil and a puddled embankment, has been allowed a velocity of 2·50 cubic feet per second. The discharge of it is supposed to be 2,945 cubic feet at Uncha Khera, which, with the 284 cubic feet from the tail of the upper portion of the Fyzabad branch (para. 62), gives a total at Uncha Khera of 3,229 cubic feet per second, or sufficient for the requirements of the Lucknow and lower portions of the Fyzabad branch.

Lucknow branch velocities.

65. The Lucknow branch has a discharge of 616 cubic feet per second and a mean velocity at head of 2·07 feet, which is reduced to 1·90 feet at Lucknow, where the discharge is 281 cubic feet. This branch, as well as the supplementary channel, is navigable.

Velocities in Fyzabad branch from Uncha Khera to Durriabad.

66. The second section of the Fyzabad branch has a discharge at its head of 2,639 cubic feet per second and a mean velocity of 2·30; in the channel passing through the clayey lands near the Kulleanee Nuddee, the mean velocity is increased to 2·50, which is retained as far as the Durriabad bifurcation.

Velocities in Fyzabad branch from Durriabad to Fyzabad.

67. The third section of the Fyzabad branch, from Durriabad to the Fyzabad bifurcation, commences with a discharge of 1,079 cubic feet and a mean velocity of 2·42 feet, which is reduced to 2·05 feet at Fyzabad bifurcation, below which there is a navigable line about 4 miles long, to connect the canal with the river Gogra, near the city of Fyzabad.

Velocities in Durriabad and Jaunpore branch.

68. At the Durriabad bifurcation, the Durriabad and Jaunpore branch, a navigable line takes out. The discharge at head is 1,236 cubic feet with a mean velocity of 2·35, which is gradually reduced to 2·02 feet until it comes within a few miles of the river Goomtee, where the soil is stiff and capable of bearing a velocity of 2·50 feet, the discharge at tail of canal being 203 cubic feet per second.

Velocities in Azimgurh branch.

69. The Azimgurh branch, which is simply an irrigating line, starts from the Fyzabad bifurcation with a discharge of 706 cubic feet and a mean velocity of 2·09, runs out at Azimgurh with a discharge of 80 cubic feet and a mean velocity of 1·84.

D.—Alignment of Canal.

Reasons for fixing on Bunbassa and Nuglah as sites for head works.

70. The reasons for fixing the head of the Canal at Nuglah, and selecting Bunbassa as the site of weir across the river Sardah were fully explained in the General Report (paragraphs 10 to 21); and the arrangements regarding the position of the head works having been fully approved of by Government of India (paragraph 32 Public Works letter

No. 363I, dated 9th October 1869), it is needless to recapitulate here the grounds on which the above results were arrived at.

Flood discharge of the river.

71. Hitherto, the cold weather supply at Bunbassa has only been referred to; but in order to get data on which to base conclusions for determining the length of the weir, &c., it is necessary to ascertain the highest flood discharges, and with this view accurate measurements were taken, not only at Bunbassa but also at Burm Deo, of the extreme limits to which floods had risen, and of the surface slope, as near as could be ascertained of the water in flood.

Referring to sketch on opposite page, it will be seen that in the highest known flood, which occured at Burm Deo,

The area of the flood discharge = 9,822 superficial feet.
Wetted perimeter = 770 feet.
∴ Hydraulic mean depth R. = 12·75.
and S, the slope of surface being 1 in 2,000.
$V = 93\sqrt{\frac{R}{S}} = 7.44$, and D = 73,076 cubic feet.

At Bunbassa, where the river is in two streams, (paragraph 10 General Report),

The area of flood discharge in the west or main branch = 9,673·50.
Wetted perimeter = 624·44.
Hydraultic mean depth. = 15·489.
S = 1 in 3,000 — V = 6·60 and D = 63,842 cubic feet.
The area in east branch = 1,950·50.
Wetted perimeter = 255·97.
Hydraulic mean depth = 7·62
S = 1 in 3,000 — V = 5·02 and D = 9·792 cubic feet.

∴ Total flood discharge at Bunbassa = 73,634, a result which, by a happy coincidence tallies almost exactly with the flood discharge at Burm Deo.

A few small mountain streams, however, fall into the river, between Burm Deo and Bunbassa, and allowing that these are in flood at the same time as the river, the discharge at Bunbassa ought to exceed that at Burm Deo. The loss by percolation between these places (paragraph 49) might possibly be taken into account as a reason why the Bunbassa discharge should not be materially greater than at Burm Deo; but, all things considered, it seems safer to admit that the above theoretical discharge of 73,634 cubic feet is below the actual result, and when computing the dimensions, &c., of the weir, the flood discharge has therefore been taken at 33 per cent. more, or 98,178 cubic feet per second.

General design of head works at Bunbassa.

72. Turning now to drawings No. 3, 4, 5, 6, which show position and details of the head works at Bunbassa, it will be seen that the general design is to put a solid weir across the east branch of the river, so as to turn the whole cold weather supply down the main or west branch, across which is the regulating dam, with the regulating bridge immediately at right-angles to it. Protecting embankments, pitched with boulders, connect the two weirs, and are carried down stream of them for some distance on either banks, and a second embankment is carried from the high land of

RIVER SARDAH

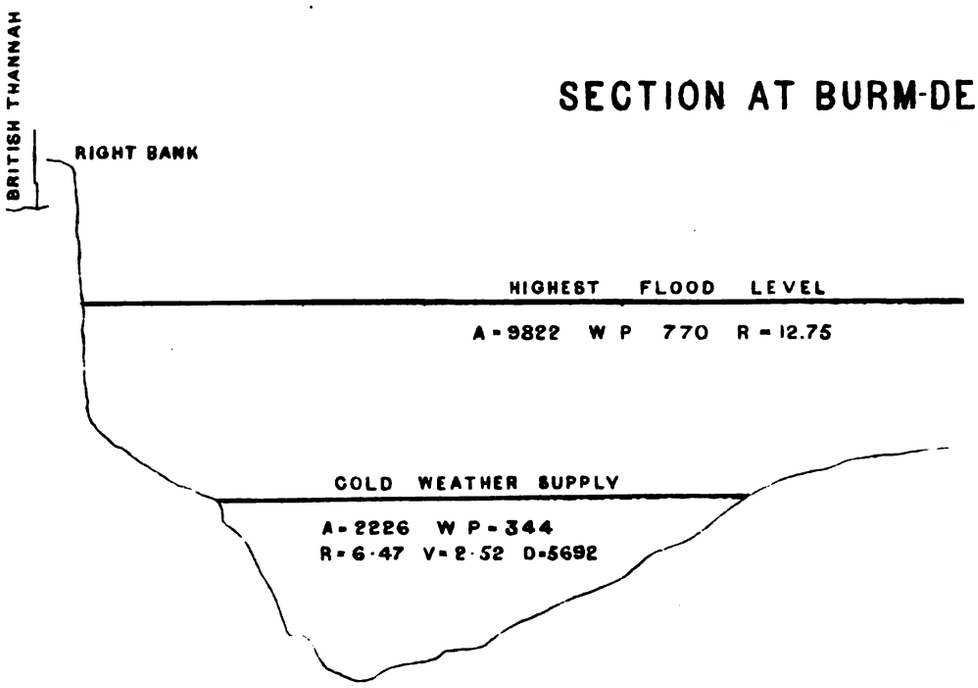
HORIZONTAL SCALE 1 INCH=120' FT.

120' 90' 60' 30' 0' 120 240'

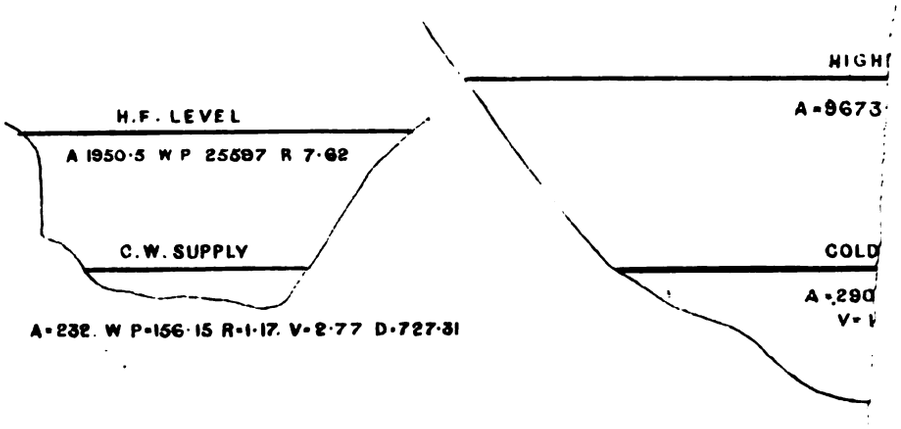
VERTICAL SCALE 1 INCH=12 FEET

12' 9' 6' 3' 0' 12' 24'

SECTION AT BURM-DE



SECTIONS AT BUNBA



Reazvodeen Draftsman

the Bangur, in a line with the regulating bridge, to the head of the island of Chandni Chok, so as to prevent the flood waters of the river from spilling into the supply channel.

Weir across east branch of Sardah.

73. The weir across the east branch of the Sardah will be built at the head of the small island that divides the river near Bunbassa.

The level of the crest is just sufficient to force the whole of the water (from January to May) round the head of the island into the main branch, but not so high as to interfere with the discharge of the river, during floods.

The length of the weir is 500 feet, which is somewhat more than the width of the river at this point during ordinary floods. The abutments and adjoining embankments are carried up to a level five feet above the highest known flood, and are pitched on the river face to within three feet of the top.

The total superficial amount of waterway in flood over the weir will be 2,500 feet, which, with a velocity of 7·62 feet, will give a discharge of 19,050 cubic feet per second.

The foundation of weir consists of a wall of boulder masonry, 12 feet broad and 10 feet in depth (8 feet below bed of river), carried completely across the stream. On this wall is built the weir, which consists of a battered wall, 6 feet high, of boulder masonry faced with blocks of squared stone 18 inches thick. Parallel to the up-stream foundation wall and 30 feet from it on the down-stream side, a curtain wall 5 feet thick, is built, the foundations being at the same level as those of the up-stream wall. The space between the up and down-stream walls will be packed with boulders and clay on which an inclined flooring will be laid extending from the crest of the weir to the down-stream curtain wall. This flooring consists of boulder masonry, 2 feet thick, with a facing of 18 inch squared stone. The inclination of this flooring is about 1 in 9. On the down-stream side, a packed boulder apron, 30 feet wide and 3 feet thick, has been estimated for. The whole of the bed of the river being composed of boulders, it was not thought necessary to extend this apron further.

The abutments of the weir consist of rubble masonry, with hammer dressed quoins; the foundations being at the same level as the body of the works.

Regulating dam across main branch of Sardah.

74. The regulating dam across the main branch of the river is 1,050 feet in length, of which 685 feet consist of a solid weir, and the remaining 365 feet of an open dam, with falling gates, so as to admit of a scour immediately in front of the regulating bridge. The clear waterway during floods will be 12,036 superficial feet, which with a velocity of 6·60 gives a discharge of 79,438 cubic feet per second. The discharge over weir across east branch being 19,050 cubic feet the total discharge over both weirs will be 98,488 cubic feet per second (*vide* para. 71.)

The solid portion of the dam is precisely the same as that already described for the east branch. The remainder will be constructed as follows:—The up and down stream curtain walls of the solid weir will be

continued under the open portion of the dam. Between these walls, and at a distance of 12½ feet from the up-stream one, a third wall 2 feet 6 inches thick will be built extending from the end of the solid part of the dam to the west abutment. Cross walls, 4 feet thick and 19 feet apart, will be built in the space included between the two up-stream walls, and brick arches, 2 feet thick, will be thrown from cross wall to cross wall, so as to form a rigid flooring, for the dam openings. Upon this flooring the piers will be built; these are 31 in number, 11 feet 6 inches apart from centre to centre, and 8 feet high. Between them there will be a horizontal flooring of squared stone which will be continued to the down-stream curtain wall. The 32 openings between piers will be fitted with drop gates 6 feet high, and 8 feet wide, worked in the same way as those now in use on other canals. This open dam will discharge upwards of 7,000 cubic feet per second with 6 feet of water in the river, or more than the cold weather supply.

Regulating bridge at head of supply channel.

75. The regulating bridge at head of supply channel will be built immediately adjoining the west end of the regulating dam and at right angles to it. It consists of a double series of arches, 6 feet span, carrying a roadway 20 feet wide, and a tramway for the traversing windlass which will raise or lower the regulating sluice gates. At the north end, an arch of 22 feet span will be thrown over the lock chamber which it is proposed to build in connection with the bridge.

The foundations of the work will consist of two curtain walls of boulder masonry, 4 feet thick and 28 feet apart, with a third wall, 3 feet thick between the two; all three walls being carried down 10 feet below the flooring of the bridge.

Cross walls 4 feet thick and 8 feet 3 inches from centre to centre, will be built between the curtain walls, and on these will be placed the piers. The foundations of abutments and lock chamber walls will be of boulder masonry carried down to a depth of 10 feet below flooring.

The number of openings in the bridge will be 41, of which the one over the lock chamber will have a span of 22 feet (closed with gates) and the remainder, spans of 6 feet each, fitted with regulating sluices.

The piers of the roadway bridge will be prolonged up-stream 8 feet beyond the face. On these prolongations, the arching for the traversing windlass will be built, having a clear space from the face wall of one foot, in which the regulating gates will work, sliding in vertical cast-iron grooves let into the piers.

The sluices for each opening will be in two pieces, each 6 feet high, so as to close the lower portion of each of the openings, for a height of 12 feet; above this the arch openings will be closed by walls 4 feet thick.

The waterway of the regulating bridge, when the river is at its lowest level, (6 feet above flooring of bridge), will be 1,572 superficial feet, and the waterway of supply channel below the bridge will be 1,554 feet.

Curve on supply channel.

76. For a distance of 1,000 feet, the supply channel is straight, but then turns round with a curve of half a mile radius (*vide* plan No. 2) in order to fall in with the old channel of river. With the exception of this

curve, and another on the Lucknow and Jaunpore branch, of 1¼ miles radius, necessitated by having to skirt the Cantonment of Lucknow, there are no curves on the canal of less than 3 miles radius. It will be seen that the half mile curve at head of supply channel is unavoidable, but there is not likely to be any cutting in it, as both the sides and bed of the channel are comprised of boulder, and the maximum velocity will not exceed 5·09.

Velocities in supply channel.

77. At 8,500 feet below the regulating bridge, it is proposed to construct a 10 feet rapid, so as to bring the bed of the supply channel down to the same level as the old bed of the dry branch of the river which goes to Nuglah.

The slope given to the supply channel between the regulating bridge and crest of rapid is 1 in 1,800, which, with the following depths of water, will give velocities and discharges as below :—

Depth of water.	*Mean velocity.*	*Discharge cubic feet per second.*
6	5·09	7,816
5	4·66	5,942
4	4·18	4,250
3	3·64	2,759

Rapid in supply channel.

78. The design for the rapid is based on those constructed on the Baree Doab Canal. It consists of an inclined bed of boulders 5 feet thick, kept in place by longitudinal and cross walls of rubble masonry, with side walls carried up to about 9 feet above the bottom of the channel. The rapid will be 312 feet between side walls, 200 feet long, with a total fall of 10 feet, or 1 in 20. Below the slope, the boulder pitching will be continued for a distance of 80 feet, and the side walls be splayed out to 342 feet.

Supply channel.

79. Below the rapid, there are two methods by which the water can be conveyed down to Nuglah, first along present channel of old branch, shown in red line on plan No. 2, and second by excavating a new channel direct down to Nuglah, as shown by the blue line on plan.

By the first scheme, no masonry works have to be built, but the slope of the bed in the river is heavy—more than 8 feet per mile—this, however, is the same as the slope of supply channel on the Ganges Canal.

By the second scheme, the channel is led down to Nuglah in a direct line, and the excessive slope of bed is overcome by building four rapids.

Taking into consideration the known fact of loss by percolation in the river between Bunbassa and Moondeea Ghát (6 miles below Nuglah), it might perhaps be thought that some allowance should be made for a similar loss on the supply channel, but the conditions are somewhat different; the water in the river spreads in very many small streams over a great width of surface, whereas in the supply channel it is confined and kept in one narrow duct, the bed of which is *below* the level of the river.

Should the second scheme, proposed above for the supply channel, ever be carried out, there is little doubt but that more water will be found at Nuglah than at Bunbassa; for it will be observed on the section

that the bed is kept well below the surface of the boulder stratum, it will therefore act, to a considerable extent, as a drain for leakage water from the river, as well as a conduit for leading the Bunbassa supply to Nuglah.

The sections along each of these lines are shown on sheets Nos. 3 and 4, but as the estimate of the second scheme is upwards of five lakhs in excess of the first, the former has been adopted.

Passage of the Jughoora torrent.

80. Between Bunbassa and Nuglah the Jughoora Nuddee falls into the supply channel. Plan No. 2 shows the arrangements which are intended to be made in order to prevent this torrent entering the channel. By a cut and bunds, the stream will be diverted into a large swamp which extends down close to Nuglah. After depositing the greater part of its silt in this swamp, the stream will be diverted by a cut into an old branch of the river (not the supply channel), and is thus led down direct to the open dam at Nuglah.

Head works at Nuglah.

Drawings Nos. 8 to 11.

81. At the end of the supply channel at Nuglah, or Kunja Bojh, the head works of the main canal are situated. At this spot, a regulating dam will be built across the river and immediately adjoining, and at right angles to it a regulating bridge and lock. The sudden change from the great slope in the supply channel to the very small inclination in the canal, will, of course, cause a considerable deposit of silt, but it will be observed, on reference to the plan and section, that for a distance of half a mile above the regulating bridge, and for a width of 800 feet, the water will be ponded up into a large reservoir, which will act as a silt trap, and by simply opening the gates of the regulating dam, the silt can be scoured out into the river below.

The Sunnea Nuddee, which at present runs at an awkward angle into the river about 600 feet above the proposed site of the regulating bridge, will be diverted into the new channel shown on plan, so as to sweep along in front of the regulating bridge. Across this diversion, a road bridge of three arches of 22 feet span, will be placed. The full supply depth of water being 12 feet, the waterway of the bridge=792 superficial feet, which is ample to carry off the highest flood discharge of the Sunnea Nuddee, which is 3,260 cubic feet per second.

Regulating dam at Nuglah.

82. The regulating dam will be built across the old bed of the Sardah at Nuglah, about 230 feet to the down-stream side of, and parallel to, the centre line of the main canal.

It will consist of a dam 1,352 feet long, provided with 112 openings of 8 feet wide. Of these, 32 at the end of the dam next the regulating bridge and 12 at the opposite end will have a flooring at the same level as that of the regulating bridge. The floorings of the remaining 68 will be 2 feet higher. The whole of the openings will be fitted with drop gates, as at Bunbassa.

When all the gates are open with 12 feet depth of water, the clear waterway will be 9,664 superficial feet, which, with a calculated velocity of 4·80 feet, will give a discharge of 46,387 cubic feet per second.

The discharge of the Jughoora Nuddee, allowing for a rain-fall of 12 inches over its catchment basin of 36 miles, is 11,629 cubic feet per second.

The area of flood section is 2,020 square feet, and the velocity due to the surface slope is 7·09 feet, giving a discharge of 14,320 cubic feet per second, or about 2,700 more than the discharge deduced from the catchment basin. The larger discharge of 14,320 cubic feet has therefore been accepted.

The discharge of the Sunnea Nuddee being 3,260 cubic feet, and of the supply channel 7,818 cubic feet per second, the total discharge through the dam need be only 25,398 cubic feet instead of 46,387 cubic feet as above, but the extra amount is allowed for, as a precautionary measure, in case any of the protective bunds at Bunbassa should be breached in high floods, and an extra amount of water from the left branch of the river enter the supply channel.

The foundations of the dam will be constructed in a similar manner to those of the open portion of the weir at Bunbassa. The whole of the curtain walls, cross walls, and abutment foundations, will be carried down to a level of 10 feet below the flooring of the regulating bridge. Every fourth pier will be 6 feet broad, and 33 feet in length, the intermediate ones being 3′ 6″ broad and 21½ feet long. It is proposed to carry up these larger piers to a height of 25 feet in order to carry a bridge, which is essentially required here, so that in all seasons it may be possible to pass over to the left bank of the supply channel to inspect the protective works on the river, without being obliged to go up to Bunbassa.

This bridge will consist of trellis girders of bar, T, and angle iron, carrying a planked roadway by means of timber cross beams attached to the bottom flanges.

The spans will be 43 feet 6 inches and the width of roadway 20 feet.

Regulating bridge at Nuglah.

83. The regulating bridge at Nuglah will be constructed in precisely the same way as that at Bunbassa. There will be 45 openings of 6 feet span, and one of 22 feet for the lock chamber.

The total waterway for a full supply depth of 12 feet, will be 3,504 superficial feet, the waterway in the canal below being 3,516.

From the west end of the regulating bridge to the bridge across the Sunnea Nuddee division, there will be built a strong retaining wall backed by a wide earthen embankment, carrying a tow path 15 feet wide, and a 20 feet roadway; a similar wall will be built at the down-stream side for a distance of 300 feet.

Chowka aqueduct.

84. At 19,600 feet from Nuglah, the canal is carried over the river Chowka by an aqueduct of 3 spans of 27 feet each (drawing No. 12) with piers 6 feet and abutments 12 feet thick, strengthened at every 15 feet, by counter forts 8 feet square.

The flooring over the aqueduct as well as on the embankment on either side of it consists of one foot of puddle, kept in place by a layer of shingle. The foundations are on wells 20 feet deep, filled in with concrete.

The highest flood discharge of the river Chowka is 1,161 cubic feet per second, and the superficial amount of waterway allowed for it is 324 square feet, which will give a velocity of less than 4 feet per second. The flooring of the river bed, is built 3 feet lower in the centre arch, than in the two side arches. This is done in order that a clear road for traffic may be left on either side of the Chowka; for, except in floods, the water in the river will pass through the centre arch only. By doing this we avoid the necessity of building an expensive bridge over the canal embankment, which otherwise would be required for the road from Khuteywar to Moondeea Ghát.

Moondeea Ghát bridge.

85. Between Nuglah and Mina Kote there is only one bridge, *viz.*, where the road from Pillebheet to Moondea Ghát crosses the canal. The length of waterway required is 278 feet, exclusive of 8 feet on each side for towing paths. The headway given to the bridge is 12 feet above full supply, and to the tow paths 6½ feet.

Seven elliptical arches of 42 feet span have been allowed for this bridge, with a roadway 20 feet broad. The soil where the bridge will have to be built is extremely bad, and the estimates are accordingly made out for well foundations sunk to a depth of 20 feet below bed.

Mina Kote trifurcation.

86. Drawings Nos. 14 to 18 show in full the details of the works at the Mina Kote trifurcation. The regulating bridges at heads of branches are essentially the same as that at Nuglah. With the exception of the Shahjehanpore branch regulating bridge, all of them are provided with locks for the passage of boats, when there is difference of level of water surface up and down-stream of the regulator.

Alignment of canal below Mina Kote.

87. The map of the Gogra-Gangetic Doab, together with the plans on the scale of one mile to an inch, attached to the section sheets, will show better than any verbal description the course of the main lines of canal below Mina Kote. By the aid of the magnificent maps recently executed by the Revenue Survey Department in Oudh, under Major Anderson, we have been enabled to trace out without possibility of error the true position of the watershed in the province. For the upper portion of the canal, in the district of Bareilly and Shahjehanpore, of which there were no good maps, elaborate surveys and accurate levels have been taken by Messrs. Heaford, Henslowe, Froude and Bull, as shown in map No. 4.

It will be observed that, with the exception of one very small nullah near the head of the Fyzabad branch, not a single drainage in the whole length of the country from Mina Kote to Benares is crossed, and only three small jhíls; there need not be any apprehension, therefore, of the supplies of tanks, &c., being interfered with.

Falls.

88. The standard plans for the 95 falls on the canal are shown in drawings Nos. 33 to 36; those on the Azimgurh and Shahjehanpore branch, which are irrigating channels, with small discharges, are designed with contracted openings, those on the main canal have the full width, and are based on the pattern of the Baree Doab Canal falls. Every fall has been provided with a masonry bridge 20 feet in width, to accommodate the traffic and facilitate the working of the falls in the event of repairs being required. The cisterns extend in length from the foot of the

crest wall to the curtain wall under the bridge; the floorings of them consist of 2 feet of brickwork over 3 feet of concrete. The tail walls which splay out from the bridge on either side, extend to a distance of 50 to 96 feet according to the discharge, &c., over the fall. The basin between the curtains and tail walls will be packed with boulders or kunkur, to a depth of 3 feet. The foundations, except wing walls of bridges will be on wells sunk to a depth of 20 feet.

Bridges.

89. There are 291 bridges, and the standard plans for them are shown in drawing No. 39. They are of two classes; 1st and 2nd, according as the roadway is of 20 or 12 feet in width. They consist of elliptical arches of varying spans, according to width of canal, the clear headway for boats being 12 feet above full supply level. All bridges are provided with tow paths 8 feet broad and 6½ feet headway under the arches on either side. As all the falls are provided with bridges, the total number of passages of communications over the canal is 386, which for the length of 1,206 miles, gives on an average about one bridge in every three miles of the canal.

Branch heads.

90. Drawings Nos. 28 to 32, show the proposed scheme of arrangements for the branch heads at Sissoree, Uncha Khera, Durriabad, and Fyzabad. They are all on the same general plan, and designed on the same principles as the one at Mina Kote. By widening out the canal and keeping the bed at a level for a mile above the branch heads, the channel will act as a silt trap, in which silt will be deposited, and by periodically opening the powerful escape heads, which are placed above the regulating heads, the whole of the silt will be scoured out into the escape nullah.

Escapes.

91. In addition to the escape at branch heads, escapes have also been estimated for at intervals of 50 miles down the canal. For the Mina Kote escape, 4 tail falls of 10 feet each have been allowed, and on other escapes one fall of 10 feet, to lower the bed of the escape into the discharging river or nullah.

Locks.

92. The designs for locks and lock channels are shown in drawing No. 38, they are the same as those on the Ganges Canal, with the exception that their dimensions are increased to 150 feet in length, and 22 feet in width. The chance of boats being dragged over the falls is so great, that it has been thought preferable to keep the locks detached from the main canal, and to place them on separate lock channels. Gratings, however, have been allowed for all falls, and the risk of boats going over is thus reduced to a minimum, but with a fluctuating supply as there will be in the Sardah Canal, it is more than probable that sleepers, instead of gratings will have to be used in order to maintain regulation, and it is on this supposition and also that the *possible maximum* expenditure may invariably be shown, that the estimates have been made out for separate lock channels.

Reason why locks on separate channels are preferred.

93. Another reason too, is that probably arrangements for navigation will not at first be needed on all the canals (*vide* para. 111,) and it will, therefore, be unnecessary to build the locks at the same time as the other works are built. By placing the locks on separate channels, they can be built at any time subsequent to the opening of canal: but by at-

taching them to the falls in the main stream, (*vide* Drawing No. 37,) they must be erected at the same time as the rest of the works, and it seems scarcely worth while sinking the large capital required for their construction, until the demand for navigation is such as to justify spending the amount required for it.

On turning to the abstract of the general estimate, it will be seen that the cost of the falls (after deducting the rapid and falls on the Shahjehanpore and Azimgurh branches, which are not navigable,) is ₹ 64,22,669; and the expenditure on account of locks is ₹. 42,49,682, which amount however, need not be spent for many years. By attaching the locks to the falls, their cost will be ₹ 101,07,963; but is it worth while expending this difference of ₹ 36,85,294? (₹ 101,07,963,—64,22,669,) at the first commencement of the works, when there will be little or no return from navigation; and diminishing the profits derivable from irrigation dues, which for many years at least will thus have to show a percentage on capital sunk solely for navigation.

The total cost of falls and separate lockage is ₹ 64,22,669 + 42,49,682 = 106,72,351. The cost of falls with locks combined, is ₹ 101,07,963; the difference in favour of the latter is, therefore, Rs. 5,64,388, a useless saving if we lose the interest on ₹ 36,85,294, for say 10 years only.

Mills.

94. Appendix E, gives the number of effective horse power, available on the 95 canal falls (when there is a supply of 6,300 cubic feet at Mina Kote, and 2,965 at head of supplementary channel) after deducting loss for irrigation, and applying a modulus of ·58. Of the whole total of 77,929 H. P., it would be absurd to expect that anything approaching to the full quantity would ever be utilised in driving machinery, say, however, that only one-ninth of the above is ultimately used, and we are in possession of water power sufficient to give profitable employment to a capital exceeding 2½ millions of pounds * for working up the raw agriculturable produce of the districts into forms best suited for export, or for home consumption. Eventually, capitalists may come forward to take advantage of the opportunity thus given them, and as it is to private enterprise we must look for the erection of mills, the cost of them has not been estimated for in this project.

Arrangements have, however, been made for utilising some portion of the water at each of the locks, for driving the common native "Punchukkí" (or corn mill) as on other canals.

Weir at Delaha.

95. Having thus briefly described the works on the main lines of canal, it is necessary to revert to the supplementary channel. Drawings Nos. 24 to 26, show the details of the head works. The weir is designed on the same principle as that recommended by the Ganges Canal Committee for the weir across the river Ganges at Sookertal. The highest flood discharge of the river Sardah at Delaha, the head of the supplementary channel, is calculated to be 108,100 cubic feet per second. With 10 feet of water passing over the weir, with 6 feet per second velocity, the discharge will be 110,800 cubic feet per second. The length of the weir is 1,525½ feet between abutments; it consists of a solid dam 1,200 feet in length,

* See memorandum on motive power for machinery on Ganges Canal, by Colonel Baird Smith.

with two sets of regulating sluices on either flank. At the end of the dam next the regulating bridge, a lock chamber is constructed for boats passing up and down the river. The solid portion of the weir consists of a wall 10 feet thick at top; the up-stream face being vertical, and the down-stream having a batter of 1 in 7. The regulating openings at each end of the dam consist of two series of twenty arches of 6 feet span, fitted with sluice gates worked in the same manner as that proposed for the works at Bunbassa and Nuglah.

At the down-stream side of the regulating openings and solid dam, a flooring consisting of 2 feet of brickwork, covered with a paving of stone one foot thick, will extend for 48 feet.

The whole of the weir, abutments, lock, and curtain walls at tail of flooring, will rest on wells 7 and 10 feet diameter, and 2 and 2½ feet thick carried down to a depth of 30 feet below bed of river. The wells below the flooring, will be 7 feet diameter, 2 feet thick, and will only be 17 feet in depth. Below the flooring, an apron of concrete blocks, or kunkur, will extend down-stream for a distance of 150 feet.

Regulating bridge, Delaha

96. The regulating bridge will be constructed in precisely the same manner as those at Bunbassa and Nuglah; with the exception that the foundations are on wells carried down 30 and 17 feet below bed, and that the lock is detached from and placed at 370 feet above the bridge. The whole of these works are connected together with strong revetment walls. 10 miles of protective embankment, *viz.*, 3 miles up-stream, and 2 miles down-stream of weir on either bank, are allowed for in the estimates.

Supplementary channel.

79. Map No. 3 shows clearly the proposed course of the supplementary channel between Delaha and Uncha Khera. Three streams are crossed, the Kundooha, Kutnia and Ool; the two former of which will be diverted by cuts into the latter, which will then have an estimated discharge of about 7,000 cubic feet per second. The canal is carried over this river by a syphon, shown in drawing No. 27, capable of discharging 7,316 cubic feet per second. One culvert for passing drainage water under the canal, where it skirts the high land; and two for the drainage of the country between the Fyzabad branch and the supplementary channel, have been estimated for.

Chokies.

98. One chokie for the accommodation of canal establishment, has been allowed for every 12 miles of canal. In the upper portion where the canal passes through malarious tracts, these chokies will have to be double storied; but on the lower sections, they have been estimated for as single storied buildings.

Workshops.

99. A lump sum of Rs. 1,00,000 has been entered down in the estimates on account of workshops, which will be required on the several divisions of the canal when work is started.

Tramway for materials.

100. Appendix A and map No. 5, give the details, &c., of a proposed tramway for the conveyance of materials from the stone and lime quarries at the head of the Jughoora Nuddee to Bunbassa; also of the cost of permanent way and rolling stock for running out the spoil from the deep digging at the head of canal to form the Chowka embankment.

Rajbuhas.

101. Maps Nos. 2 and 4, show the proposed arrangement for rajbuhas or distributing channels, from the Shahjehanpore and upper portion of the Fyzabad branches. In other sections, three miles of rajbuhas have been allowed for each mile of canal.

Rates of labour, &c.

102. The rates of labour, cost of materials, &c., on which the estimates are based, are shown in Appendix F.

Amount of land required.

103. Appendix D. shows that 74,834 acres of land are required for the canal and its distributing channels.

SECTION IV.

Expenditure and Income.

Probable cost of Sardah Canal.

104. The estimate for the Sardah Canal (as per details in the accompanying sixteen volumes) is Rs. 544,42,971, to which must be added Rs. 65,33,157 (12 per cent.) on account of establishment, and Rs. 7,39,110 on account of tramway, or a grand total, of Rs. 617,15,238, (*vide* statement on opposite page) for main channels 1,206 miles in length, capable of discharging 10,780 cubic feet per second (7,835 at Nuglah, and 2,945 at Delaha), or at the rate of Rs. 51,173 per mile of canal, and Rs. 5,725 per cubic foot of discharge.

Cause of difference between original and present estimate.

105. In the rough estimate forwarded with the general report, the probable cost based on the averages of four canals was put down at Rs. 4,000 per cubic feet of discharge; on the supposition that the average velocities of 2½ to 3 feet could also be maintained on the Sardah Canal. Better information has shown, however, that an average velocity of from 2 to 2¼ feet per second is all that can with safety be allowed; and this circumstance alone, has added most materially to the expense. An inspection of the plans and estimates will also show that the fullest allowance has been given to every item; every one of the falls on the main canals are supposed to be founded on wells; whereas, actually in carrying out the work, these deep foundations will probably not be required in *all* the falls, but only in a few; the rates of excavation vary from a minimum of Rs. 2-4 to Rs. 9-13, and do not, as in other canals, include turfing banks and slopes, which alone amounts to Rs. 15,07,105.

Again, the boulder flooring below falls and bridges has been extended to a greater distance than usual, causing a difference of Rs. 3,36,478 on the whole estimate; admit that gratings are not required at falls (*vide* also paras. 92 and 93,) and that sleepers can be used instead; and the cost will again be reduced by Rs. 7,02,867.

Maximum expenditure estimated for.

106. Analysing the estimate in this way, it will be seen that by clipping rates; cutting out what may possibly be considered extraneous items; and above all by the perilous adoption of a standard velocity of 2½ to 3 feet, the cost of the Sardah Canal may be reduced to less than Rs. 5,000 per cubic foot of discharge, or little more than the original estimated cost of the Baree Doab Canal. The main object, however, that has steadily been kept in view, is to show in an open and clear light, the *maximum* cost of the Sardah Canal, and not to prepare an "*ad captandum*" estimate showing the lowest possible sum for which the works might be constructed.

SARDAH CANAL.

ABSTRACT OF GENERAL ESTIMATE.

	Main line to Mina Kote.	Shajehanpore branch.	Benares branch.	Lucknow and Jaunpore branch.	Fyzabad branch.	Lucknow branch.	Durriabad and Jaunpore branch.	Azimghur branch.	Grand Total.
Channel excavation, including turfing, &c., ...	34,23,426	2,83,533	69,11,351	36,36,900	41,97,491	3,52,380	8,81,356	3,71,119	2,00,57,556
Drainage works, including head works, ...	17,17,153	12,240	...	...	16,97,838	...	...	...	34,27,231
Overfalls and rapids, ...	65,076	54,173	30,50,471	9,86,501	17,62,264	2,78,222	3,45,211	27,812	65,69,730
Bridges, including branch heads, ...	4,89,283	40,420	17,91,035	12,06,871	15,62,151	2,17,902	5,00,905	2,98,403	61,06,970
Lockage, including navigation channels, ...	...	...	15,54,947	8,67,252	11,79,720	2,71,407	3,76,356	...	42,49,682
Escape channels, including earthwork, turfing, heads, and falls, ...	9,57,962	...	9,31,034	6,03,581	6,39,997	...	...	...	31,32,524
Accommodation for establishment, ...	57,412	40,716	2,16,714	1,42,506	1,89,856	33,930	61,074	47,502	7,89,710
Fencing, ...	5,548	20,040	1,47,840	78,420	78,840	17,820	34,320	27,060	4,09,888
Irrigation outlets (rajbuhas,)	...	3,85,000	28,73,000	12,52,500	16,63,000	4,52,500	8,67,000	6,10,000	81,03,000
Compensation for land, ...	43,560	35,860	5,71,580	2,48,440	3,44,400	68,760	1,24,820	59,260	14,96,680
Workshops, ...	20,000	...	30,000	20,000	30,000	...	...	...	1,00,000
TOTAL.	67,79,420	8,71,982	180,77,972	90,42,921	133,45,557	16,92,921	31,91,042	14,41,156	544,42,971
Establishment, ...	8,13,530	1,04,638	21,69,358	10,85,150	16,01,467	2,03,150	3,82,925	1,72,939	65,33,157
Tramway for materials.	7,39,110	...	...	...	..	...	...	...	7,39,110
TOTAL, ...	83,32,060	9,76,620	202,47,330	101,28,071	149,47,024	18,96,071	35,73,967	16,14,095	
GRAND TOTAL, ...									617,15,238

SARDAH CANAL.

General Abstract.

Branch.	Total of Section.	Total of Branch.
1. Central Line to Mina Kote, ...	... ...	75,92,950
2. Shahjehanpore, Branch, ...	... ...	9,76,620
3. Benares Branch—		
Section No. 1	75,11,790	
„ No. 2	48,91,945	
„ No. 3	52,03,292	
„ No. 4	26,40,303	202,47,330
4. Lucknow and Jaunpore Branch—		
Section No. 1	49,48,289	
„ No. 2	51,79,782	101,28,071
5. Fyzabad Branch—		
Section No. 1	53,54,037	
Supplementary Channel, ...	35,14,142	
Section No. 2	43,21,502	
„ No. 3	17,57,343	149,47,024
6. Lucknow Branch, ...	... ...	18,96,071
7 Durriabad and Jaunpore Branch, ...	... ...	35,73,967
8. Azimghur Branch, ...	... ...	16,14,095
Total Rupees. ...	... ...	609,76,128
Add Tramway, ...	... ...	7,39,110
Grand Total Rupees,	... ...	617,15,238

Gross Annual Revenue.

107. The statement in para. 41 shows that, in estimating the probable number of acres that will be watered by the canal, a discharge of 9,539 cubic feet per second is all that has been taken into account; and on the assumption that instead of 296 only 250 acres are watered per cubic foot of discharge, 23,84,750 acres will annually be irrigated, which, at the low rate of Rs. 2-8-0 per acre, will give a return of Rs. 59,61,875.

The miscellaneous dues, on account of navigation, &c., being taken in the same proportion to water rate as on the Ganges Canal, will give a further sum of Rs. 4,32,614, and the total gross revenue, per annum, will therefore be Rs. 63,94,489.

Annual expenditure.

108. The annual expenditure in maintenance on the Ganges Canal is Rs. 152 per cubic foot of water entering the canal, and on the Eastern Jumna Canal Rs. 102; the extra amount on the Ganges Canal being caused by the repairs entailed in consequence of the great velocity in the channel. We may fairly, in the case of the Sardah Canal, where every precaution has been taken against excessive velocity, accept the lower rate. The annual charges on 10,780 cubic feet per second entering the canal will then be Rs. 10,99,560.

The cost (Rs. 14,96,680) of the land required for the canal and its distributaries being included in the estimates, no deduction is made on account of the yearly loss of revenue on the ground thus occupied.

Net income.

109. The annual gross returns being Rs. 63,94,489, and the expenditure Rs. 10,99,560, the net income will be Rs. 52,94,929, or a return of more than 8½ per cent. on the capital.

Method of carrying out the work by sections.

110. Thus we see that, even under unfavourable circumstances, when the expenditure is taken at a maximum, and the probable income estimated at a most moderate limit, the Sardah Canal will pay a fair percentage on the capital invested; years though must elapse, after the water is admitted into the canal, before the full stan dard of irrigation is attained, and consequently, before the above dividend can be realized. The canal, however, can be made by branches, and as each one comes into play, and returns begin to be derived from it, others can be commenced.

Allowing nine years for the construction of each of the sections, as proposed in the following paras. (111-114) the entire capital of six millions need not be called up for 36 years.

First section.

111. By carrying out the works as proposed in para. 41 of General Report, *viz.*, constructing first only the Shahjehanpore, Fyzabad (to Uncha Khera,) and Lucknow Branches, which run through land where water is most urgently in demand, and leaving in abeyance the remainder of the project, the estimate shows that the cost will be—

	Rs.
Head Works to Mina Kote, including trifurcation, and tramway for materials, ...	83,32,060
Shahjehanpore Branch, ...	9,76,620
Fyzabad Branch to Uncha Khera, ...	53,54,037
Lucknow Branch, ...	18,96,071
Total, ... Rs.	165,58,788

The statement in para. 41 shows that 508,000 acres will probably be irrigated, *viz.*, on

	Acres.
Shahjehanpore Branch, ...	87,750
Fyzabad Branch to Uncha Khera, ...	266,250
Lucknow „	154,000
Total, ...	508,000

which at Rs. 2-8 per acre, will give an annual water rate of Rs. 12,70,000; adding Rs. 1,00,000 for miscellaneous dues, the gross income will be Rs. 13,70,000. The maintenance charges on 2,500 cubic feet of water entering the canal at Rs. 102 per cubic foot being Rs. 2,55,000, the net income will be Rs. 11,15,000 or more than 6 per cent.

But it must be recollected that the above sum of Rs. 165,58,788 includes the full cost of the heavy Chauká embankment, and of the cutting above Mina Kote, also of the expensive trifurcations and escapes at that place and at Uncha Khera. All these works, however, are not wanted for the limited supply required for the Fyzabad and Shahjehanpore branches:—the banks of the Chauká embankment instead of being raised to their full height of 14 feet need only be made 9 feet; the regulating bridge at the head of the Benares branch need not be built, nor is it necessary that the escapes at Mina Kote and Uncha Khera, should be dug out to their full extent, the whole of the massive works at the latter place will not be required, nor need the locks on the lines be provided at first. Deducting the amounts on account of these, *viz.*, lockage Rs. 9,21,127, and Rs. 12,00,000 *on account of the other items, the cost will be Rs. 144,37,661, and the net income being Rs. 10,15,000, the return will be a little more than 7 per cent.

Second section.

112. The next line to be completed would be the Benares branch, from Mina Kote to Benares, the cost of this as per abstract on page 74B, = Rs. 202,47,330, to which must be added Rs. 11,00,000 left unspent (para. 111.) on portion of canal between Mina Kote and Nuglah, or a total of Rs. 213,47,330.

The number of acres that will be irrigated = 7,55,500 (para. 41)

Water rent, ...	Rs.	18,88,750
Adding miscellaneous dues, ...	„	1,50,000
Gross Revenue, ...	„	20,38,750
Deduct maintenance, ...	„	3,57,000
Net annual income, ...	„	16,81,750

which, on Rs. 213,47,330, gives a return of 8 per cent.

Third section.

113. The Jaunpore line would then be commenced.

The cost is, ...	Rs.	101,28,071	
Area irrigated, ...		4,55,750	acres.
Water rate, ...	„	11,39,375	
Miscellaneous revenue, ...	„	90,000	
Gross revenue, ...	„	12,29,375	
Deduct maintenance,	„	1,88,700	
Net annual income,	„	10,40,675	

or 10 per cent. on the capital.

* Rs. 11,00,000 due to Benares Branch, and Rs. 1,00,000 to Fyzabad Branch.

Fourth section.

114. After the above branches are finished, the supplementary channel and the lower portions of the Fyzabad branch could be completed.

The cost of these works (with Rs. 1,00,000 unspent on upper portion of Fyzabad branch) is Rs. 148,81,049 and 6,65,500 acres will be irrigated, the water rate therefore will be Rs. 16,63,750, and the miscellaneous dues about Rs. 1,10,000.

The gross income therefore will be,...	Rs.	17,73,750
Deducting maintenance, ...	„	3,06,000
Net annual income, ...	„	14,67,750

or 9 per cent. on the capital.

SECTION V.

Miscellaneous.

Modifications of scheme.

115. Many modifications of the above scheme for the Sardah Canal will doubtless present themselves to the mind. In preparing the project, however, the intention has been not only to prepare such a plan as would suffice for the irrigation of the entire area between the Gogra and Ganges, but also, in the event of its being finally determined that water is not required for the whole of this tract, that the estimates and details should be so complete that by mere inspection and slight alteration they could be re-cast so as to show the cost of any alternative proposition that might be brought forward.

Work done.

116. The work done in the preparation of the project has been considerable.

Upwards of 4,300 miles of levels have been taken; 7,500 square miles of country surveyed; 50 river discharges measured; 2,300 bench marks noted; 103½ miles of centre line of canal permanently marked out; 6 temporary chowkies built; and 11 trial wells sunk. Appendix G shows the differences between reduced levels of canal and Great Trigonometrical Survey bench marks between Benares and Pillibheet (360 miles), closing in at the latter station with a difference of ·13 only, the credit of which accurate levelling is chiefly due to Mr. Handcock, by whom five-sixths of the work on this line was done. In the intermediate bench marks larger differences than the above, occur; the maximum being ·70; but in the circle completed by the Great Trigonometrical Survey it will be observed that there is admitted to be an error in their work of ·64.

In addition, the officers of the Revenue Survey in Oudh were engaged in running a series of cross sections from the Ganges to the Gogra at intervals of 10 miles from Allahabad upwards; the season's work for 1868-69, comprising six sections (with the exception of reduced level of bench marks), has only been received up to date; but when the remainder of the sections are completed, they will form a valuable ground work for a contour survey of Oudh. The splendid maps of the Revenue Survey

Department showing, in the greatest detail, the topographical features of the country, have been of the greatest assistance (*vide* para. 87) in fixing the positions of the canal lines.

117. Appendix K shows the total expenditure incurred on account of the Sardah Canal from the commencement of the preliminary surveys in January 1868, up to 1st September 1870. The total is Rs. 2,04,358, *which includes cost of chowkies, wells, lining out, &c.*, notwithstanding these charges, however, it will be observed that the rate is only Rs. 170 per mile, for the 1,206 miles of canal projected; a rate which it is trusted will be considered satisfactory when it is remembered that in England the cost of making only the preliminary surveys and getting up a project for a railway, which does not involve so much labour as a canal project, is estimated at £30 or Rs. 300 per mile.

Acknowledgments.

118. In the preparation of this project, most cordially and efficiently have I been assisted by all the officers engaged with me on the work.

On Messrs. Heaford and Handcock, Executive Engineers, Messrs. Henslowe, Clark, Froude and Bull, Assistant Engineers, devolved the task of carrying out the extensive survey and levelling operations, required as a basis for the project; of plotting sections, and preparing maps. To Mr. Scott, Executive Engineer, and Messrs. Ledger and Keelan was assigned the duty of preparing designs, and working out estimates, of all the masonry works on the canal; and to Mr. Parsick, Assistant Engineer, was entrusted the laborious business of estimating the whole of the earth-work in the canal, with the exception of the upper portion, which was estimated by Messrs. Heaford and Froude.

The designs for the falls, shown in drawings 33 to 36, were made by Mr. Handcock; those for the head works at Bunbassa, Nuglah (or Kunja Bojh), and Delaha, by Mr. Ledger; those for the trifurcations and for the fall with lock combined, by Mr. Keelan; and the remainder by Mr. Scott.

The sections of the upper portion of the canal and of the Fyzabad branch are based on the surveys and levels of Messrs. Heaford, Froude and Bull; those of the Shahjehanpore and upper portions of the Benares and Jaunpore Branch on Mr. Henslowe's levels; and the lower portions of the above branches and the whole of the Lucknow Branch on levels taken by Mr. Handcock. The lower portion of the Fyzabad Branch from Sera Mow to Fyzabad was levelled by Mr. Froude, and the Durriabad and Azimgurh lines by Mr. Clark.

J. G. FORBES, Captain, R. E.,
Officiating Superintending Engineer,
Sardah Canal.

APPENDICES.

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APPENDIX A.

TRAMWAY FOR MATERIALS.

APPENDIX A.

FROM

T. E. HEAFORD,

EXECUTIVE ENGINEER,

Irrigation Works, Oudh.

To

CAPTAIN J. G. FORBES, R. E.,

SUPERINTENDING ENGINEER,

Irrigation Works, Oudh.

Dated 6th August 1870.

SIR,

Complying with your instructions, I have examined (with a view of constructing a line of Railway) the ground between Bunbassa and the Quarries (stone and lime) at the head of the Jugboora Nuddee. Having taken flying survey and levels, I have now to submit the result of this inspection.

2. The time I could spare to this work (about a fortnight), and the difficult nature of the ground which is altogether covered by dense tree, bamboo and cane jungle, allowed me (assisted by Mr. Froude) to do little more than run one trial section and a few cross sections on the side-long ground near the Jugboora head.

The section No. 2, sent herewith, and the estimate based upon it are therefore likely to show an unduly high cost. A careful setting out of the line can scarcely fail to result in improvement.

3. Near the little village of Kalonia the Jugboora emerges from the hills through a deep gorge. About a mile and a half within this gorge, on the east side of the river and overlooking it from a height of about 700 feet, is the lime which you discovered last year and to which you directed my attention.

Near the foot of the hill at the top of which the lime lies is a stone quarry. The stone is good, can be had of any size required, and can be "got" without difficulty. Moreover, the site is easier of access than any other good stone quarry I have been able to find.

To this point I propose that Locomotives should run.

4. The lime lies too high to be accessible to Locomotives (except at vast expense), but between it and the stone quarry there is an even slope down the side of the hill. No difficulty whatever exists in making an inclined plane connecting these two sites. Laden waggons should be made to draw up empties.

5. From the stone quarry to the face of regulator is a distance of nearly 10½ miles. The last ¾ mile is intended to be a double line.

6. As the centre line is not set out on the ground, it would waste time to make designs and drawings of works which may ultimately prove inapplicable, but I have made rough sketches of some of them from which to take out quantities and thus to ensure reasonable accuracy in the estimate.

These sketches I send herewith, and you will see that the quantities they show in each work are ample, in some cases perhaps even excessive.

Curves, gradients, &c.,

7. The curves (considering the gauge and the proposed rolling-stock) are very easy. Even when scarping the hill side near the stone quarry, where the running will be necessarily slow, no curve of less radius than 600 feet will be required.

As the average fall from one end of the line to the other is as great as 1 in 85, comparatively steep gradients are unavoidable, still the worst part of the line (about one mile of 1 in 35) presents no difficulty in working, especially as only empty trains will have to ascend the incline.

Position of line.

8. For the first mile and a half the line scarps the hills on the left of the Jugboora. After that it runs over very favourable ground.

From sketch No. 1, it will be seen that the railway goes straight from Kalonia to the Hela swamp, curves round it on the high ground to the site fixed for the crossing of the Hoodi Nuddee, and then takes a direction straight for the Bunbassa headworks of the canal.

Gauge.

9. The estimate is based on the assumption that a 3 feet 6 inches gauge will be adopted.

When high speed and the conveyance of a large number of passengers are not conditions demanded, it possesses several economic advantages over the gauge in use in this country.

It is open to doubt whether these advantages would not be more than counterbalanced by the evils of a break of gauge, if the proposed work were likely to be connected with existing lines, but as this is most unlikely I have no hesitation in suggesting the adoption of a gauge which recommends itself by economy and the excellent working of which in Norway, I have had occasion to enquire into and to admire. It has also successfully stood the test of experience in Queensland.

Earthwork.

10. With very little exception the line from Bunbassa to Kulonia (9 miles) runs over ground consisting of boulders and gravel; from Kalonia to the quarry (1½ miles) the hill side is rock, some weathered, some in fragments, some still solid and requiring powder for excavation.

Sketches Nos. 4 and 5, show dimensions of cuttings and banks in the first named 9 miles. Those for the upper part are estimated for in the same dimensions (although they safely admit of reduction on the rocky ground) except that the slopes are reduced to ½ to 1 and 1 to 1 respectively.

Retaining walls.

11. Scarping along the hill side, it will be in many places advantageous to have a low retaining wall instead of running the bank out at its usual slope; this will be particularly the case where the hill side is very steep, and where the small hill torrents are crossed.

I propose to put these walls together of dry rubble, for which plenty of large stone will be obtainable from the upper side. Sketch No. 6, shows the dimensions on which the estimate is framed. I am not in possession of sufficient data to arrive at a detailed estimate, and have therefore assumed a wall 4 feet high all along the banks in addition to the full quantity of earthwork as per section. This is probably in excess of what will be actually expended; but here, as in every other doubtful case, I have carefully avoided under estimating the money required.

Level crossings.

12. Two roads only are crossed by the proposed line, and the traffic on them is not so great as to call for an expensive crossing.

Sketch No. 7 shows the kind of crossing estimated for. I have added Rs. 150 to this part of the estimate to cover expense of temporary small crossings which no doubt will have to be provided for the accomodation of cattle belonging to the hill-men, who occupy this country during the winter season.

Bridges and Culverts.

13. There is only one stream of importance to cross, *viz.*, the Hoodi Nuddee. Two others, whose names I do not know, appear to carry down a large volume of water during the rains, but, unlike the Hoodi, they are not perennial.

These three streams I propose to cross by temporary bridges consisting of longitudinal balks (on which the rails are dogged) supported by timber pieces or tressels standing on stout wooden sills. The railway will not—indeed, for some time to come, cannot—be in use during the rains. At the end of each working season, the timber is to be removed and stacked, to be again put together on the resumption of work. On a line intended only for temporary use (say 8 years) it does not appear desirable to incur the great expense involved in building permanent bridges calculated to resist the violent torrents, which these apparently paltry streams grow to in summer. Sketch No. 8 shows roughly what is proposed.

The small hill streams in the first mile and a half are intended to be crossed by a couple of balks framed together in the usual way, and supported by abutments of good dry rubble.

I do not think the span will in any case exceed 12 feet.

Two (perhaps three) smaller culverts should be provided. Sketch No. 9 shows what is estimated for.

The embankment is retained by the two side walls of the culvert. These are built of dry rubble if suitable stone is at hand, if not, then of pucca brickwork.

The permanent way is carried over on two balks of timber which rest on a well packed frame of cross sleepers. I have not thought it desirable to rest the balks on the side walls. To do so is to make a hard rigid point in the otherwise slightly elastic line.

Unless the rails are very constantly and carefully lifted and regulated on both sides of these rigid points, the percussion of every train not only shakes the best of masonry to pieces, but is also seriously detrimental to the rolling stock.

Permanent way.

14. The permanent way is of 3 feet 6 inches guage. The rail is flat footed and weighs 42lbs per lineal yard. Resting on bed plates, it is fastened down to wooden cross sleepers by fang bolts screwed tight on the under side by nut and washer.

There will be 1,760 sleepers to the mile, and three-fourths of these may, for the sake of economy, be of half round wood, round side uppermost, adzed to receive the bed plates. The joints are hanging, *i. e.*, they are between sleepers and unsupported, but are well fished. Sketch No. 3 shows the general arrangement, and in the estimate will be found the weights of the several parts.

I must here account for an apparent incongruity in the design of this railway, while everything else is calculated for a temporary line only, while the bridges are temporary timber structures, and culverts and retaining walls are intended to be of dry rubble, the permanent way is made to have a strength and finish equal to the regular conveyance of a large passenger traffic. The line is no doubt absolutely required for the efficient construction of the Sardah Canal works ; considering the quantity of stone and lime required, the size of the stone, the difficulty of access to the quarriers, the distance of the carriage, and the nature of the country and roads, it would be economy to provide a locomotive track at almost any price. Still, as there is no probability of its being required for any other purpose after completion of the Canal (say eight years), it is desirable to sink as little capital as possible, no more than is absolutely necessary to keep it in efficiency during that time.

After careful consideration, I have come to the conclusion, that economy is to be ensured only by laying down in the first instance, a permanent way much superior in ballasting and fastening to what a quarry line would seem to require.

Bunbassa is very inaccessible, not only by reason of being so far from the sea-board, but by its distance from the nearest pucca road, and from the nearest point to which water carriage is available. It seems probable that the ironwork from England, when delivered on the ground, will (freight and charges included) amount to nearly treble the prime cost.

Hence it is important to get as little iron as possible from home, and to take every care that none of it, (especially rails, which make so large a proportion of the weight) should require renewal.

The rail must be made to last unrenewed until the Canal works are finished, which time we now estimate at 6 or 7, but which unforeseen delays may extend to 10 years. No rails of reasonable weight, fastened as is usual on temporary lines, could stand the work these will be subjected to for even the shorter of the periods mentioned ; to be safe for the longer period, it is necessary to have rails new, of good quality, and to expose them to a minimum of unfair wear and tear. The extra cost of the strong fastenings designed to comply with the last condition represents only 11 per cent. of the sum, which renewal of the rails would involve.

I have no means of ascertaining what rails it is proposed to use on the Indian State Railways, but would suggest that if any rail of suitable strength and tread for our purpose, is being or intended to be imported by the Government of India, our rails should be of the same pattern. Whether we want a few odd rails, or whether we find at the end of the work that some fairly sound rails are to spare, it would be a considerable advantage to have rails interchangeable with some railway in permanent work. The one shown is sketched by me, not (as far as I am aware) a rail of standard dimension.

The expense of delivering iron at Bunbassa is one reason for the use of wooden instead of iron sleepers. The line runs through forest jungle, and sleepers, as proposed, can be had in any quantity on the spot. Of course they will all require renewing, but the cost of this will bear no comparison with that of iron sleepers.

The risk of breakage, too, would be large on so long a journey over bad roads, and moreover the ballast (coarse gravel and small boulders), which is abundant, though fairly good for wooden sleepers, would not be safe for iron ones, unless it were broken up much smaller.

I do not think anything further about the permanent way calls for present remark, unless it be the proposed fastening of the fang bolts on the underside of the sleeper.

In my opinion, no road is safe on cross sleepers with ordinary dogs, however strong. On longitudinal sleepers, the case is different, and on the balks across the bridges, I propose merely to use dog-spikes. In the latter case, the small vertical wave-like motion of the rail in front of the advancing train is not only diminished, but is nearly coincident with that of the timber to which it is fastened.

On a cross sleeper road, there is a strong tendency to spring the bolts, and I have more than once seen the locomotive endangered by a spike being jumped into the machinery. Of course, jagged spikes would prevent nearly all risk of the kind, but they are very objectionable in a permanent way.

It is difficult, often impossible, to draw them when you want them out, in the case of renewing a sleeper or the like.

Cast iron chairs and wood keys suggested themselves, but the weight of chair and consequent expense is against them, they also require constant supervision lest the keys get loose.

I have laid down and had to maintain many miles of road fastened in the manner sketched, and although using principally coloured labour, found no difficulty either in first laying down or in maintenance.

Rolling stock.

15. The curves on the proposed line admit of almost any rolling stock being used. I have estimated for ordinary four-wheeled trucks and ordinary contractors' tank engines.

If, however, it be contemplated by the Government to extend the use of a 3 feet 6 inches gauge, or if the gauge of this line be altered so as to agree

with any in general use in India, I would suggest the application of Clark's radial axles to the waggons, and more particularly the use of locomotives on Fairlie's principle. The former will enable the waggons to be used at any future time on any line on which it may be found economical to employ the sharpest curves, and the advantages of the latter are, I believe, beginning to be known and appreciated. An ordinary tank engine will do our work, but will not after that be worth much, if anything.

An engine on Fairlie's principle can be relied on for many years' service, and during its working, will be economical not only in current expense for fuel, &c., but also in the outlay for repairs.

Of course, the engines will be adapted for the burning of wood.

Sundries.

16. I have not entered into any detailed estimate of tools and plant required; as much as may be wanted for construction and laying the permanent way is included in the prices put down in the estimate, but I have, under the head of Sundries, added the sum of Rs. 20,000 for pumps, hose, &c., for locomotive water supply, and for the supply of tools and sundries, which are necessary to effect minor repairs to locomotives and rolling stock generally.

Estimate.

An estimate of cost of the whole work is as under. The large sum I have allowed for carriage of ironwork to Bunbussa has raised the average price quite to £4,000 a mile, but, as far as I can see, this item could not be reduced without risk of understating the probable outlay which this work will demand.

JUGBOORA QUARRIES' RAILWAY ESTIMATE.

Jungle clearance.

			Rs.
Say 50 acres at, ...	Rs. 80		4,000

Inclined Plane (1,680 feet long).

Forming road, ...	Rs.	6,720	
Rails (including 10 per cent. for turn-outs),	„	4,600	
Spikes (ditto ditto), ...	„	875	
Sleepers (ditto ditto), ...	„	616	
Rollers, ...	„	1,680	
Rope (wire), ...	„	3,500	
Drum and shed, ...	„	2,000	
			19,991

Earthwork.

2,264,000 cubic feet rock @ Rs. 20, ...	45,280	
1,366,000 ordinary cutting @ Rs. 5, ...	6,830	
3,223,000 ordinary side cutting @ Rs. 2-8, ...	8,058	
Side ditching 18 miles @ Rs. 100, ...	1,800	
		61,968

Retaining walls.

65,000 cubic feet @ Rs. 100, ...	6,500

Level crossings.

Two main crossings @ Rs. 50, ...	100		
Say for temporary cattle crossings, ...	150		
			250

Bridges.

Hoodi Nuddee, ...	Rs.	4,000	
Two smaller streams @ Rs. 600, ...	„	1,200	
Seven hill streams „ „ 175, ...	„	1,225	
			6,425

Culverts.

Three six or eight feet culverts @ Rs. 150, ...			450

Permanent way.

In each mile.

Rails 66 tons, @ Rs. 200	13,200		
Bed plates 6¾ „ „ 180	1,991		
Fang bolts 6⅕ „ „ 300	1,860		
Fish plates 22 cwt. „ „ 22	594		
Fish bolts 9 „ „ „ 30	270		
Sleepers No. 1760 „ „ 1	1,760		
Ballast 89,760, Cubic feet (17 cb. ft. per ft. lin.), @ Rs. 3,	2,693		
Lifting, trimming and regulating, ...	500		
	Rs.	22,868	per mile.

Length of line ...	10½ miles.		
Double line ...	¾ „		
	11¼		
10 per cent. for siding, cost of points, &c.,	1¼ „		
Say 12½ miles @ Rs. 22,868			285,850

Rolling stock.

60 waggons (iron work) @ Rs. 300, ...	18,000		
Do. (wood-work) „ „ 100, ...	6,000		
2 Locomotives, @ £3,000, ...	60,000		
			84,000
Sundries, ...			20,000
		Rs.	489,434
Contingencies, 5 per cent.,	„		24,472
	Rs.		513,906

Comparison of Jugboora line with line to Burm Deo.

18. For several reasons it would have been preferable to run a line to the stone quarries above Burm Deo rather than to the Jugboora head.

Burm Deo already, has a considerable trade which is annually increasing. It is not improbable that even during construction of Bunbassa head-works, the line might have earned something by conveyance of produce. Possibly, it might prove worth while after completion of the works to maintain the line as between Burm Deo (a principal market

for trans-Himalayan produce) and Bunbassa (the head of a navigable canal) the cheapest highway towards most parts of India.

I have a few levels in this part of the country, and, assisted by your protraction and levels taken two years ago, have made a rough estimate for comparison with the one now submitted.

A permanent line to Burm Deo would no doubt be more expensive than one to the Jugboora, as four considerable streams have to be crossed, but on the assumption that these are to be dealt with by temporary structures similar to the one herein proposed for the Hoodi Nuddee, the cost of the line would be as nearly the same as possible to the cost of the one now estimated for, if there were any difference, I think it would be in favour of the Burm Deo line.

There is only one objection to the adoption of the latter, but this one objection is fatal. The Jugboora line runs to stone and lime quarries, the Burm Deo line to a stone quarry only. There are abundunt indications of the presence of lime in the neighbourhood. Most of the small streams from these hills are found to deposit lime in greater or less quantity in their beds, but although rewards have been offered for the discovery of a sufficient supply of lime, I am not aware of any considerable quantity having been found. Before leaving these parts last spring, I pointed out to some hill men, well acquainted with the country, the direction in which lime might be found, desired them to search for it, and renewed the promise of a handsome reward if they succeeded in finding a suitable supply.

Should they be successful, it would for many reasons be desirable to take the line of Railway to Burm Deo instead of to the Jugboora head; otherwise, not even the many advantages of the former would outweigh the one great advantage of being able to obtain both stone and lime from sites within little more than ¼ mile of each other, both sites being accessible to waggons running on rails.

19. Since I commenced this letter, you have desired me to state the probable sum required for rails, &c., in the working of large cutting and embankment near Putsa. Putsa embankments.

I do not think we should have less than 8 miles of rails, &c., as the bank must be worked from both ends. In that case the cost will be about Rs. 225,204 as under :—

Rails per mile, 66 tons @ Rs. 300, ...	13,200	
Spikes, &c., per mile, 44 mds. @ Rs. 25, ...	1,100	
Sleepers, per mile, 1,760 mds. @ Rs. 1, ...	1,760	
	Say Rs.	16,060 per mile.
8 miles, @ Rs. 16,060, ...	108,480	
2 Locomotives, @ £3,000, ...	60,000	
120 Waggons, @ Rs. 300, ...	36,000	
Sundries, ...	10,000	
Contingencies, @ 5 per cent.	10,724	
	Rs.	225,204

Nothing is charged for laying the road down, as that labour is fairly chargeable to the earth-work. So also will be the relaying and slewing of the road and renewal of sleepers.

Good fastenings are here not estimated for, because ordinary spiking down of the rails will better serve the purpose where the road-way is constantly being shifted, as must be the case in those exceedingly wide cuttings and banks.

Tools, &c., for repairs of Rolling stock are not estimated for, on the assumption that all that may be required will be done by the shops attached to the Jugboora Quarries' Line.

The waggons intended to be provided will of course be tip-waggons. There is no difficulty in altering some of these toward the end of the work, so as to make them tip-sideways in making good whatever may be required in trimming the slopes.

The item sundries represents the probable cost of pump, tank, hose, cock-post, piping, cinder-pit, &c., and of a locomotive shed in which to house the engines during the rains.

I have the honour to be,
Sir,
Your most obedient servant,

(Sd.) T. E. HEAFORD,
Executive Engineer,
Irrigation Works, Oudh.

P. S.—I have estimated nothing for land, under the impression that all the country we cross is the property of Government.

Abstract showing probable amount of materials that will have to be carried by tramway.

Boulders,	Puddle,	Lime stone,	Stone,	Shingle,	Earthwork in embankment,	
...	...	...	...	...	...	HEAD WORKS TRIFURCATION.
...	...	36,300	2,17,736	...	...	Solid dam at Banbassa.
...	...	65,525	3,93,150	...	...	Regulating dam at Banbassa.
...	5,490	33,000	1,79,773	19,186	...	Regulating bridge and lock at Banbassa.
...	...	30,230	1,67,565	...	...	10 Rapid.
...	...	1,05,559	4,24,058	...	...	Regulating dam at Kunjah Bojh.
...	1,800	9,055	16,531	16,531	...	Sunnea bridge.
...	6,180	82,083	2,30,318	...	...	Regulating bridge at Kunjah Bojh.
...	...	7,04,200	...	42,25,985	11,00,00,000	Chooka embankment.
...	...	1,87,817	...	1,74,351	...	Chooka aqueduct.
54,400	...	1,62,512	...	22,531	...	Moondeea ghát bridge.
...	...	...	...	...	...	MINA KOTE TRIFURCATION.
1,55,587	8,970	52,757	...	30,344	...	Escape head.
94,635	5,016	54,450	...	43,296	...	Fyzabad branch head.
1,89,481	8,080	69,954	...	47,503	...	Benares branch head.
38,175	1,575	29,916	...	16,237	...	Shahjehanpoor branch head.
2,10,960	10,320	1,44,623	...	96,260	...	Four Escape falls.
...	...	...	...	...	...	SHAHJEHANPOOR BRANCH.
6,210	2,536	8,668	...	...	...	Nos. 1 and 2 falls.
...	...	6,700	...	...	...	Nos. 1 and 2 bridges.
...	...	...	...	...	...	Benares branch.
1,00,926	43,031	93,194	...	...	...	No. 1 bridge and fall.
1,91,322	81,242	1,77,563	...	...	...	No. 2 and 3 ditto.
4,160	4,600	31,315	384	...	...	No. 1 lock.
8,320	9,600	53,851	768	...	...	No. 2 and 3 ditto.
...	...	...	...	...	...	FYZABAD BRANCH.
49,260	22,087	44,047	...	...	...	No. 1 bridge and fall.
44,850	19,887	40,745	...	...	...	No. 2 ditto ditto.
42,338	...	12,452	...	...	...	No. 1 and 2 bridges.
8,320	9,200	60,195	...	...	...	No. 1 and 2 locks.
11,98,944	2,39,614	22,96,711	16,33,283	46,92,224	11,00,00,000	Total of each kind.
	12,00,57,776					Grand total in cubic feet.

APPENDIX B.

SARDAH CANAL.

Abstract of General Estimate.

Description.	Main line to Mina Kote.	Shahjehanpoor Branch.	Benares Branch.	Lucknow and Jounpoor Branch.	Fyzabad Branch.	Lucknow Branch.	Durriabad and Jounpoor Branch.	Azimgurh Branch.	Grand Total.
	Rs.	Rs.	Rs,	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.
Channel excavation, including turfing, &c., ...	34,23,426	2,83,533	69,11,351	36,36,900	41,97,491	3,52,380	8,81,356	3,71,119	200,57,556
Drainage works, including head works, ...	17,17,153	12,240	..	..	16,97,838	..	..	..	34,27,231
Overfalls and rapids, ...	65,076	54,173	30,50,471	9,86,501	17,62,264	2,78,222	3,45,211	27,812	65,69,730
Bridges, including branch heads, ...	4,89,283	40,420	17,91,035	12,06,871	15,62,151	2,17,902	5,00,905	2,98,403	61,06,970
Lockage, including navigation channels, ...	..	..	15,54,947	8,67,252	11,79,720	2,71,407	3,76,356	..	42,49,682
Escape channels, including earthwork, turfing, heads and falls,	9,57,962	..	9,31,034	6,03,531	6,39,997	..	..	..	31,32,524
Accommodation for establishment, ...	57,412	40,716	2,16,714	1,42,506	1,89,856	33,930	61,074	47,502	7,89,710
Fencing, ...	5,548	20,040	1,47,840	78,420	78,840	17,820	34,320	27,060	4,09,888
Irrigation outlets (rajbuhas), ...	..	3,85,000	28,73,000	12,52,500	16,63,000	4,52,500	8,67,000	6,10,000	81,03,000
Compensation for land, ...	43,560	35,860	5,71,580	2,48,440	3,44,400	68,760	1,24,820	59,260	14,96,680
Workshops, ...	20,000	..	30,000	20,000	30,000	..	..	..	1,00,000
Total, ...	67,79,420	8,71,982	1,80,77,972	90,42,921	1,33,45,557	16,92,921	31,91,042	14,41,156	544,42,971
Establishment, ...	8,13,530	1,04,638	21,69,358	10,85,150	16,01,467	2,03,150	3,82,925	1,72,939	65,33,157
Tramway for materials, ...	7,39,110	..	..	..	..	..	..	..	7,39,110
Total, ...	83,32,060	9,76,620	202,47,330	101,28,071	149,47,024	18,96,071	35,73,967	16,14,095	..
GRAND TOTAL, ...	..	..	..	..	..	..	..	Rs., ..	617,15,238

APPENDIX C.

Tabular Statement, showing Nature and Position of Masonry Works, and Changes in Sectional Area and Slope of Canal Channel, with consequent Velocities and Discharges.

Distance from head in feet.	Width of bottom of channel.	Depth of water.	Slope of bed.	Bottom velocity in feet per second.	Mean velocity in feet per second.	Discharge cubic feet per second calculated.	Description of Works.
				MAIN LINE FROM BUNBASSA TO MINA KOTE.			
							Solid dam on east branch of the Sardah at Bunbassa 500 ft. long.
							Regulating dam at west branch of the Sardah at Bunbassa 1050 ft. long.
...	250	6	1 in 1800	3·89	5·09	7816	Regulating bridge and lock at head of supply channel at Bunbassa, waterway of bridge and lock 262 ft.
8600	...	...	...	...	...	...	A rapid, Fall 10 ft., 21 bays of 12 ft.
40000	...	...	...	...	...	...	Regulating dam at Kunjah Bojh 1,352 ft. long.
7 miles 3040 feet.							
...	...	12	...	...	...	...	Bridge across Sunnea Nuddee Diversion, 3 spans of 22 ft.
...	275	12	1 in 23000	1·51	1·97	6935	Regulating bridge and lock at Kunjah Bojh, at head of Main Canal.
19650	275	12	1 in 23000	1·51	1·97	6935	Aqueduct over the river Chooka, 3 spans of 27 ft.
53400	257	12	1 in 23000	1·51	1·97	6632	Moondeea Ghât bridge, 7 spans of 42 ft. roadway 20 ft.
72567	249	...	1 in 23000	1·51	1·96	6310	TRIFURCATION AT MINA KOTE.
...	216	12	...	...	...	...	HEAD OF ESCAPE CHANNEL.
							Regulating bridge, 20 ft. roadway, 36 span of 6 ft.
	102	7	...	...	...	...	HEAD OF FYZABAD BRANCH.
							Regulating bridge and lock, 17 spans of 6 ft. each.
	186	12	...	...	...	...	HEAD OF THE BENARES BRANCH.
							Regulating bridge and lock, 31 spans of 6 ft. each.
	36	5	...	...	...	...	HEAD OF THE SHAHJEHANPOOR BRANCH.
							Regulating bridge 20 ft. roadway, 6 spans of 6 ft. each.
13 miles 3924 feet.							

APPENDIX C.—*(Continued.)*

Distance from head in feet.	Width of bottom of channel.	Depth of water.	Slope of bed.	Bottom velocity in feet per second.	Mean velocity in feet per second.	Discharge cubic feet per second calculated.	Description of works.
				ESCAPE CHANNEL.			
	192	12	1 in 15000				No. 1, Escape Fall, 18 bays of 12 ft. Fall 10 ft.
							„ 2, do. do., 18 do. 12 ft. Fall 10 ft.
							„ 3, do. do., 18 do. 12 ft. Fall 8 ft.
							„ 4, do. do., 18 do. 12 ft. Fall 8 ft.
				SHAHJEHANPOOR BRANCH.			
...	28	5	1 in 8000	1·512	1·976	351	Trifurcation at Mina Kote.
12000	...	...	...	...	...	...	No. 1, 1st class bridge, 1 span of 35 ft.
20000	...	...	...	...	...	...	„ 1, bridge and contracted fall, 1 bay of 10¾ ft., Fall=7 ft.
37000	27	5	...	1·507	1·969	340	„ 2, 1st class bridge, 1 span of 35 ft.
46000	...	...	...	...	...	...	„ 2, bridge and contracted fall, 1 bay of 10¾ ft. Fall=7 ft.
69000	27	4	1 in 5000	1·738	2·271	300	„ 3, do. do. do. do.=10 ft.
79000	26	4	...	1·732	2·264	290	„ 3, 1st class bridge, 1 span of 35 ft.
96000	...	...	...	...	...	...	„ 4, do. do.
104200	...	...	...	...	...	...	Mala Aqueduct, 1 span of 10 ft,
108000	...	...	...	...	...	...	No. 4, Bridge and contracted fall, 1 bay of 10¾ ft. Fall=5 ft.
124000	25	4	...	1·727	2·257	280	„ 5, 2nd class bridge, 1 span of 35 ft.
138000	...	...	...	...	...	...	„ 5, bridge and contracted fall, 1 bay of 10¾ ft. Fall=7 ft.
151000	15	4	...	1·646	2·151	180	„ 6, 1st class bridge, 1 span of 20 ft.
158000	...	...	...	...	...	...	„ 6 bridge and contracted fall, 1 bay of 5¾ ft. Fall=5 ft.
170000	15	3	...	1·456	1·903	112	„ 7, 2nd class bridge, 1 span of 20 ft.
183000	...	...	...	1·426	1·865	93	„ 7, bridge and contracted fall, 1 bay of 5¾ ft. Fall=5 ft.
194000	12	3	...	...	1·864	...	„ 8, 2nd class bridge, 1 span of 20 ft.

205000	...	...	...	1·408	1·840	80	„ 8, bridge and contracted fall, 1 bay of 5¾ ft. Fall=5 ft.
221000	10	3	...	...	1·840	80	„ 9, 2nd class bridge, 1 span of 14½ ft.
239000	...	...	...	...	...	...	„ 10, 2nd do. do., 1 do., of 14½ ft.
256000	...	...	...	...	...	...	„ 11, 1st do. do., 1 do., of 14½ ft.
273000	...	...	...	...	...	...	„ 12, 1st do. do., 1 do., of 14½ ft.
289000	...	...	...	...	...	...	„ 9, bridge and contracted fall, 1 bay of 4 ft. Fall=5 ft.
305000	3	3	...	1·243	1·624	36	„ 13, 2nd class bridge 1 span of 7½ ft.
320000	3	3	...	1·243	1·624	36	„ 14, 2nd do. do., 1 do. of 7½ ft.
327000	...	...	...	...	...	...	„ 15, 2nd do. do., 1 do. of 7½ ft.
331000	...	...	...	...	...	...	„ 16, 2nd do. do., 1 do. of 7½ ft.
333000	...	...	...	...	...	...	„ 10, bridge and contracted fall, 1 bay of 1¼ ft. Fall=10 ft.
334000	...	...	...	...	...	...	„ 11, do. do., 1 do. 1¼ ft. Fall=20 ft.
63 miles 1360 feet.							

BENARES BRANCH.

Section No. 1.

...	192	12	1 in 23000	1·486	1·942	4894	Mina Kote Trifurcation.
6000	190	11½	1 in 20000	1·563	2·042	4867	No. 1, bridge and fall, 18 bays of 12 span, Fall=10 ft.
...	...	...	...	...	...	...	„ 1, lock.
30000	188	11½	1 in 2000	1·562	2·041	4818	„ 2, bridge and fall, 17 do. do. do.
...	...	...	...	...	...	...	„ 2, lock.
50000	188	11½	1 in 20000	1·562	2·041	4818	„ 3, bridge and fall, 17 do. do. do.
...	...	...	...	...	...	...	„ 3, lock.
70000	186	11½	1 in 20000	1·562	2·041	4768	„ 4, bridge and fall, 17 do. do. do.
...	...	...	...	...	...	...	„ 4, lock.
100000	190	11	1 in 20000	1·532	2·001	4546	„ 5, bridge and fall, 17 do. do. do.
...	...	...	...	...	...	...	„ 5, lock.
120000	190	11	1 in 20000	1·532	2·001	4546	„ 6, bridge and fall, 17 do. do. do.
...	...	...	...	...	...	...	„ 6, lock.

APPENDIX C.—*(Continued.)*

Distance from head in feet.	Width of bottom of channel.	Depth of water	Slope of bed.	Bottom velocity in feet. per second.	Mean velocity in feet per second.	Discharge cubic feet per second calculated.	Description of works.
				BENARES BRANCH.—(*Continued.*)			
140000	188	11	1 in 20000	1·530	2·000	4500	No. 7, bridge and fall, 17 bays of 12 spans, Fall=10 ft.
...	...	...	...	...	...	...	„ 7, lock.
165000	184	11	1 in 20000	1·530	1·999	4408	„ 8, bridge and fall, 17 do. do. do.
...	...	...	...	...	...	...	„ 8, lock.
180000	...	...	...	...	...	...	„ 1, 2nd class bridge, 5 spans of 44 ft.
200000	180	10	1 in 15000	1·690	2·208	4305	„ 9, bridge and fall, 17 bays of 12 ft. Fall=10 ft.
...	...	...	...	...	...	...	„ 9, lock.
224000	...	...	...	...	...	...	„ 2, 2nd class bridge, 5 spans of 42 ft.
245000	178	10	1 in 15000	1·688	2·206	4259	„ 10, bridge and fall, 16 bays of 12 ft. Fall=10 ft.
...	...	...	...	...	...	...	„ 10, lock.
268000	...	...	...	...	...	...	„ 3, 2nd class bridge, 5 spans of 42 ft.
290000	176	10	1 in 15000	1·687	2·205	4212	„ 11, bridge and fall, 16 bays of 12 ft. Fall=10 ft.
...	...	...	...	...	...	...	„ 11, lock.
307000	...	...	...	...	...	...	BIFURCATION AND ESCAPE AT SISSOREE.
							Head of No. 1, Escape Channel, 32 bays of 6 ft.
							Head of Jounpoor branch, 13 do. 6 ft.
							Head of Benares branch, 14 do. 6 ft.
							No. 1, escape fall, 16 bays of 12 ft. Fall=10 ft.
58 miles 760 feet.							
				Section No. 2.			
15000	62	9	1 in 15000	1·913	2·50	2340	No. 1, 1st class bridge, 3 spans of 40 ft.
30000	91	9	1 in 10000	1·913	2·50	2316	„ 1, bridge and fall, 9 bays of 12 ft. Fall=10 ft.

...	...	...	...	...	...	...		„ 1, lock.	
50000	...	...	...	...	...	...		„ 2, 2nd class bridge, 3 spans of 40 ft.	
70000	...	...	...	...	...	...		„ 3, 2nd do. 3 do. of 40 ft.	
90000	... 106	8	1 in 10000	1·821	2·38		2248	„ 2, bridge and fall, 9 bays of 12 ft.	Fall=10 ft.
...	...	...	...	...	...	...		„ 2, lock.	
110000	...	...	...	...	...	...		„ 4, 2nd class bridge, 3 spans of 45 ft.	
130000	104	8	1 in 10000	1·821	2·38		2207	„ 5, 2nd do., 3 do. of 45 ft.	
150000	...	...	...	...	...	...		„ 6, 2nd do., 3 do. of 45 ft.	
170000	103	8	1 in 10000	1·814	2·37		2187	„ 7, 1st do., 3 do. of 45 ft.	
190000	...	...	...	...	...	...		„ 8, 2nd do., 3 do. of 45 ft.	
210000	101	8	1 in 10000	1·814	2·37		2147	„ 9, 2nd do., 3 do. of 45 ft.	
230000	...	...	...	...	...	...		„ 10, 2nd do., 3 do. of 43 ft.	
240000	100	8	1 in 10000	1·814	2·37		2126	„ 3, bridge and fall, 9 bays of 12 ft.	Fall=6 ft.
...	...	...	...	...	...	...		„ 3, lock.	
260000	...	...	...	...	...	...		„ 11, 2nd class bridge, 3 spans of 43 ft.	
280000	... 98	8	1 in 10000	1·806	2·36		2086	„ 12, do., 3 do. of 43 ft.	
300000	...	...	...	...	...	...		„ 13, 1st do., 3 do. of 43 ft.	
320000	96	8	1 in 10000	1·814	2·37		2046	„ 14, 2nd do., 3 do. of 43 ft.	
340000	...	...	...	...	...	...		„ 15, do., 3 do. of 41 ft.	
345000	...	...	...	...	...	...		„ 2, escape, 18 do. of 6 ft.	
...	...	...	...	...	...	...		„ 2, escape fall, 9 bays of 12 ft.	
360000	94	8	1 in 10000	1·814	2·37		2005	„ 16, 2nd class bridge, 3 spans of 41 ft.	
380000	...	...	...	...	...	...		„ 17, 2nd do., 3 do. of 41 ft.	
400000	93	8	1 in 10000	1·814	2·37		1984	„ 4, bridge and fall, 9 bays of 12 ft.	Fall=10 ft.
400000	...	...	...	...	...	...		„ 4, lock.	
420000	...	...	...	...	...	...		„ 18, 1st class bridge, 3 spans of 41 ft.	
440000	91	8	1 in 10000	1·806	2·36		1944	„ 19, 2nd do., 3 do. of 41 ft.	
460000	...	...	...	...	...	...		„ 20, 2nd do., 3 do. of 40 ft.	

Distance from head in feet.	Width of bottom of channel.	Depth of slope.	Slope of bed.	Bottom velocity in feet per second.	Mean velocity in feet per second.	Discharge, cubic feet per second calculated.	Description of works.	
				BENARES BRANCH.—(*Continued.*)				
480000	90	8	1 in 10000	1·806	2·36	1924	„ 21, 2nd class bridge, 3 spans of 40 ft.	
500000	...	...	...	...	...	...	„ 22, 2nd ditto 3 do. of 40 ft.	
520000	88	8	1 in 10000	1·806	2·36	1884	„ 23, 2nd ditto 3 do. of 40 ft.	
540000	88	8	1 in 10000	1·806	2·36	1884	„ 24, 2nd ditto 3 do. of 40 ft.	
550000	86	8	1 in 10000	1·806	2·36	1844	„ 5, bridge and fall, 8 bays of 12 ft.	Fall=10 ft.
...	...	...	...	...	...	...	„ 5, lock.	
563500	...	...	...	...	...	...	„ 25, railway bridge, and diversion, &c.	
564000	...	...	...	...	...	...		
				Section No 3.				
580000	86	8	1 in 10000	1·806	2·36	1844	„ 1, 1st class bridge, 3 spans of 38 ft.	
596000	...	...	...	...	...	...	„ 2, 2nd ditto 3 do. of 38 ft.	
610000	84	8	1 in 10000	1·806	2·36	1803	„ 3, 2nd ditto 3 do. of 38 ft.	
626000	...	...	...	...	...	...	„ 4, 2nd ditto 3 do. of 37 ft.	
640000	83	8	1 in 10000	1·806	2·36	1782	„ 5, 2nd ditto 3 do. of 37 ft.	
655000	...	...	...	...	...	...	„ 6, 2nd ditto 3 do. of 37 ft.	
670000	82	8	1 in 10000	1·806	2·36	1762	„ 7, 1st ditto 3 do. of 37 ft.	
685000	...	...	...	...	...	...	„ 8, 2nd ditto 3 do. of 37 ft.	
700000	100	7	1 in 10000	1·714	2·24	1730	„ 1, bridge and fall, 8 bays of 12 ft.	Fall=10 ft.
...	...	...	...	...	...	...	„ 1, lock,	
710000	...	...	...	...	...	...	„ 9, 2nd class bridge, 3 spans of 42 ft.	
725000	...	...	...	...	...	...	„ 10, 2nd ditto 3 do. of 42 ft.	
740000	98	7	1 in 10000	1·714	2·24	1697	„ 11, 2nd ditto 3 do. of 42 ft.	

756000	....		...	...	...	...	...		„ 12, 2nd ditto 3 do. of 42 ft.
770000		97	7	1 in 10000	1·706	2·23		1680	„ 13, 1st ditto 3 do. of 42 ft.
786000	...		...	...	...	...	...		„ 14, 2nd ditto 3 do. of 42 ft.
800000		95	7	1 in 10000	1·706	2·23		1647	„ 15, 2nd ditto 3 do. of 42 ft.
816000	...		...	...	...	...	...		„ 16, 2nd ditto 3 do. of 40 ft.
830000		94	7	1 in 10000	1·706	2·23		1631	„ 17, 2nd ditto 3 do. of 40 ft.
837000	...		...	...	...	...	...		„ 3, escape, 17 spans of 6 ft.
...	...		...	...	...	...	...		„ 3, escape fall, 9 bays of 12 ft.
846000	...		...	...	...	...	...		„ 18, 2nd class bridge, 3 do. of 40 ft.
860000		92	7	1 in 10000	1·699	2·22		1597	„ 19, 1st ditto 3 do. of 40 ft.
876000	...		...	...	...	...	...		„ 20, 2nd ditto 3 do. of 39 ft.
890000		91	7	1 in 10000	1·699	2·22		1581	„ 21, 2nd ditto 3 do. of 39 ft.
905000	...		...	...	...	...	...		„ 22, 2nd ditto 3 do. of 39 ft.
920000		90	7	1 in 10000	1·699	2·22		1564	„ 23, 2nd ditto 3 do. of 39 ft.
935000	...		...	...	...	...	...		„ 24, 2nd ditto 3 do. of 39 ft.
950000		88	7	1 in 10000	1·699	2·22		1531	„ 25, 1st ditto 3 do. of 39 ft.
966000	...		...	...	...	...	...		„ 26, 2nd ditto 3 do. of 38 ft.
980000		87	7	1 in 10000	1·699	2·22		1514	„ 27, 2nd ditto 3 do. of 38 ft.
995000	...		...	...	...	...	...		„ 28, 2nd ditto 3 do. of 38 ft.
1010000		85	7	1 in 10000	1·699	2·22		1481	„ 29, 2nd ditto 3 do. of 38 ft.
1025000	...		...	...	...	...	...		„ 30, 2nd ditto 3 do. of 38 ft.
1040000		84	7	1 in 10000	1·699	2·22		1465	„ 31, 1st ditto 3 do. of 38 ft.
1055000	...		...	...	...	...	...		„ 32, 2nd ditto 3 do. of 37 ft.
1070000		82	7	1 in 10000	1.691	2·21		1432	„ 33, 2nd ditto 3 do. of 37 ft.
1086000	...		...	...	...	...	...		„ 34, 2nd ditto 3 do. of 36 ft.
1100000		81	7	1 in 10000	1·691	2·21		1416	„ 2, bridge and fall, 8 bays of 12 ft. Fall=6 ft.
...	...		...	...	...	...	...		„ 2, lock.
1120000		80	7	1 in 10000	1·691	2·21		1399	„ 35, 2nd class bridge, 3 spans of 36 ft.

APPENDIX C.—(*Continued.*)

Distance from head in feet.	Width of bottom of channel.	Depth of slope.	Slope of bed.	Bottom velocity in feet per second.	Mean velocity in feet per second.	Discharge, cubic feet per second calculated.	Description of Works.	
				BENARES BRANCH.—*(Continued.)*				
1135000	80	7	1 in 1000	1·691	2·21	1399	No. 36, 2nd class bridge, 3 spans of 36 ft.	
1150000	...	...	...	...	...	...	„ 4, escape, 15 spans of 6 ft.	
...	...	...	...	...	...	...	„ 4, escape fall, 8 bays of 12 ft.	
...	...	...	...	...	...	...	„ 3, bridge and fall, 8 bays of 12 ft.	Fall=3 ft.
...	...	...	...	...	...	...	„ 3, lock.	
217 miles 4,240 feet.								
				Section No. 4.				
0	75	5	1 in 8000	1·622	2·12	874	Bifurcation at Saroun.	
15000	...	...	...	...	...	...	No. 1, 1st class bridge, 3 spans of 33 ft.	
30000	71	5	1 in 8000	1·615	2·11	829	„ 2, 1st ditto 3 do. of 33 ft.	
45000	...	...	...	...	...	...	„ 3, 2nd ditto 3 do. of 32 ft.	
60000	68	5	1 in 8000	1·615	2·11	796	„ 4, 2nd ditto 3 do. of 32 ft.	
75000	68	5	1 in 8000	1·615	2·11	796	„ 5, 2nd ditto 3 do. of 31 ft.	
90000	64	5	1 in 8000	1·607	2·10	751	„ 6, 1st ditto 3 do. of 31 ft.	
105000	...	...	...	...	...	...	„ 7, 2nd ditto 2 do. of 44 ft.	
120000	60	5	1 in 8000	1·599	2·09	706	„ 8, 2nd ditto 2 do. of 44 ft.	
135000	...	...	...	...	...	...	„ 9, 2nd ditto 2 do. of 42 ft.	
150000	56	5	1 in 8000	1·592	2·08	661	„ 10, 2nd ditto 2 do. of 42 ft.	
165000	...	...	...	...	...	...	„ 11, 1st ditto 2 do. of 40 ft.	
180000	54	5	1 in 8000	1·592	2·08	639	„ 12, 2nd ditto 2 do. of 45 ft.	
200000	67	4	1 in 7000	1·561	2·04	594	„ 1, bridge and fall 5 bays of 12 ft.	Fall=3ft.
...	...	...	...	...	...	...	„ 1, lock.	

215000	...	...	...	...	...	...							
230000	62	4	1 in 7000	1·553	2·03	554							
245000	...	...	...	...	...	...							
260000	57	4	1 in 7000	1·546	2·02	511							
275000	...	...	...	...	...	...							
290000	52	4	1 in 7000	1·538	2·01	467							
305000	...	...	...	...	...	...							
320000	47	4	1 in 7000	1·530	2·00	422							
335000	...	...	...	...	...	...							
350000	43	4	1 in 7000	1·523	1·99	385							
365000	...	...	...	...	...	...							
380000	40	4	1 in 7000	1·515	1·98	358							
400000	37	4	1 in 7000	1·515	1·98	330							
424000	45	3	1 in 600	1·454	1·90	281	„ 2	bridge and fall	4 bays of 12 ft.		Fall=10 ft.		
...	...	...	...	...	...	...	„ 2	lock.					
440000	45	3	...	1·454	1·90	281	„ 3	bridge and fall	4	do. „ 12 ft.	do.		
440500	45	3	...	1·454	1·90	281	„ 3	lock.					
440500	45	3	...	1·454	1·90	... 281	„ 4	bridge and fall	4	do. „ 12 ft.	do.		
...	...	...	...	...	...		„ 4	lock.					
441000	45	3	...	1·454	1·90	281	„ 5	bridge and fall	4	do. „ 12 ft.	do.		
...	...	...	...	...	...	...	„ 5	lock.					
441500	45	3	...	1·454	1·90	281	„ 6	bridge and fall	4	do. „ 12 ft.	do.		
...	...	...	...	...	...	...	„ 6	lock.					
442000	45	3	...	1·454	1·90	281	„ 7	bridge and fall	4	do. „ 12 ft.	do.		
...	...	...	...	...	...	...	„ 7	lock.					
83 miles 4760 feet													

„ 13 2nd class bridge 2 spans of 45 ft.

„ 14 2nd ditto 2 do. of 45 ft.

„ 15 1st ditto 2 do. „ 42 ft.

„ 16 2nd ditto 2 do. „ 42 ft.

„ 17 2nd ditto 2 do. „ 40 ft.

„ 18 2nd ditto 2 do. „ 40 ft.

„ 19 2nd ditto 2 do. „ 37 ft.

„ 20 1st ditto 2 do. „ 37 ft.

„ 21 2nd ditto 2 do. „ 35 ft.

„ 22 2nd ditto 2 do. „ 35 ft.

„ 23 2nd ditto 2 do. „ 33 ft.

„ 24 2nd ditto 2 do. „ 33 ft.

„ 25 1st ditto 2 do. „ 33 ft.

APPENDIX C.—(*Continued.*)

Width of bottom of channel.	Distance from head in feet.	Depth of slope.	Slope of bed.	Bottom velocity in feet. per second.	Mean velocity in feet per second.	Discharge cubic feet per second calculated.	Description of works.
				LUCKNOW AND JOUNPOOR BRANCH.			
				Section No. 1.			
...	85	8	1 in 10000	1·806	2·36	1823	Sissoree Bifurcation, &c.
20000	84	8	1 in 10000	1·806	2·36	1803	No. 1, bridge 2nd class, 3 spans of 37 ft.
40000	83	8	1 in 10000	1·806	2·36	1782	„ 1, bridge and fall, 8 bays of 12 ft. Fall=6 ft.
...	...	...	...	...	...	...	„ 1, lock.
60000	82	8	1 in 10000	1·806	2·36	1762	„ 2, 1st class bridge, 3 spans of 37 ft.
80000	81	8	...	1·806	2·36	1742	„ 2, bridge and fall, 8 bays of 12 ft. Fall=6 ft.
...	...	...	...	...	...	...	„ 2, lock.
100000	80	8	1 in 10000	1·806	2·36	1721	„ 3, 2nd class bridge, 3 spans of 37 ft.
120000	98	7	1 in 10000	1·706	2·23	1697	„ 3, bridge and fall, 8 bays of 12 ft. Fall=6 ft.
...	...	...	...	...	...	...	„ 3, lock.
140000	97	7	1 in 10000	1·706	2·23	1680	„ 4, 2nd class bridge, 3 spans of 41 ft.
160000	96	7	1 in 10000	1·706	2·23	1664	„ 4, bridge and fall, 9 bays of 12 ft. Fall=6 ft.
...	...	...	...	...	...	...	„ 4, lock.
180000	95	7	1 in 10000	1·706	2·23	1647	„ 5, 2nd class bridge, 3 spans of 41 ft.
200000	93	7	...	1·706	2·23	1614	„ 6, 1st ditto, 3 do. 41 ft.
220000	92	7	...	1·699	2·22	1597	„ 7, 2nd ditto, 3 do. 39 ft.
240000	91	7	1 in 10000	1·699	2·22	1581	„ 5, bridge and fall, 9 bays of 12 ft. Fall=6 ft.
...	...	...	...	...	...	...	„ 5, lock.
260000	90	7	1 in 10000	1 699	2·22	1564	„ 8, 2nd class bridge, 3 spans of 39 ft.
280000	89	7	1 in 10000	1·699	2·22	1548	„ 9, 2nd class bridge, 3 spans of 39 ft.
290000	88	7	1 in 10000	1·699	2·22	1531	„ 6, bridge and fall, 8 bays of 12 ft. Fall=6 ft.
...	...	...	...	...	...	...	„ 6, lock.

310000		87	7	1 in 10000	1·699	2·22		1514	„ 10, 2nd class bridge, 3 spans of 38 ft.
330000		86	7	1 in 10000	1·699	2·22		1498	„ 11, 2nd ditto 3 do. 38 ft.
350000		84	7	1 in 10000	1·699	2·22		1465	„ 12, 2nd ditto 3 do. 38 ft.
370000		83	7	1 in 10000	1·691	2·21		1449	„ 13, 1st ditto 3 do. 37 ft.
390000		82	7	1 in 10000	1·691	2·21		1432	„ 14, 2nd ditto 3 do. 37 ft.
401000	...		...	...	...	...	...		„ 1, escape, 16 bays of 6 ft.
...	...		...	...	...	...	...		„ 1, escape fall, 8 bays of 12 ft. Fall=10 ft.
410000		81	7	1 in 10000	1 691	2·21		1416	„ 15, 2nd class bridge, 3 spans of 36 ft.
430000		80	7	1 in 10000	1·691	2·21		1399	„ 16, 2nd ditto 3 do. 36 ft.
450000		79	7	1 in 10000	1·691	2·21		1383	„ 17, 2nd ditto 3 do. 36 ft.
460000		78	7	1 in 10000	1·691	2·21		1366	„ 7, bridge and fall, 8 bays of 12 ft. Fall=10 ft.
...	...		...	...	...	...	...		„ 7, lock.
480000		77	7	1 in 10000	1·691	2·21		1350	„ 18, 2nd class bridge, 3 spans of 35 ft.
500000		76	7	1 in 10000	1·683	2·20		1333	„ 19, 2nd ditto 3 do. 35 ft.
520000		74	7	1 in 10000	1·683	2·20		1301	„ 20, 2nd ditto 3 do. 35 ft.
528000	...		...	...	...	...	...		„ 21, 2nd ditto 3 do. 34 ft.
533000	...		...	...	...	...	...		„ 22, 2nd ditto 3 do. 34 ft.
538000	...		...	...	...	...	...		„ 23, 1st ditto 3 do. 34 ft.
542000		74	7	1 in 10000	1·683	2·20		1301	„ 8, bridge and fall, 7 bays of 12 ft. Fall=10 ft.
...	...		...	...	...	...	...		„ 8, lock.
543000	...		...	...	...	...	...		„ 24, railway bridge.
542000	...		...	...	...	...	...		„ 2, escape, 14 spans of =6 ft. „ 2, escape fall, 7 bays of 12 ft. Fall=10 ft.
					Section No. 2.				
545000		70	6	1 in 10000	1·569	2·05		970	„ 1, 1st class bridge, 3 spans of 32 ft.
550000	...		...	...	...	...	...		„ 2, ditto 3 do. of 32 ft.
555000	...		...	...	...	...	...		„ 3, ditto 3 do. of 32 ft.
560000	...		...	...	...	...	...		„ 4, ditto 3 do. of 32 ft.
573000	...		...	...	...	...	...		„ 5, 2nd ditto 3 do. of 32 ft.

APPENDIX C.—(*Continued.*)

Distance from head, in feet.	Width of bottom of channel.	Depth of water.	Slope of bed.	Bottom velocity, in feet per second.	Mean velocity in feet per second.	Discharge, cubic feet per second calculated.	Description of works.	
				LUCKNOW AND JOUNPOOR BRANCH.—				
				Section No. 2.—(Continued.)				
590000	70	6	1 in 10000	1·569	2·05	970	No. 6, 2nd class bridge, 3 spans of 32 ft.	
610000	...	...	...	...	...	...	„ 7, ditto 3 do. of 32 ft.	
630000	...	...	...	...	...	...	„ 8, ditto 3 do. of 32 ft.	
650000	...	...	...	...	...	...	„ 9, 1st ditto 3 do. of 32 ft.	
670000	...	...	...	...	...	...	„ 10, 2nd ditto 3 do. of 32 ft.	
690000	...	...	...	...	...	...	„ 11, 2nd ditto 3 do. of 32 ft.	
710000	...	...	...	...	...	...	„ 12, 2nd ditto 3 do. of 32 ft.	
730000	...	...	...	...	...	...	„ 13, 2nd ditto 3 do. of 32 ft.	
740000	60	5	1 in 8000	1·599	2·09	706	„ 1, bridge and fall, 7 bays of 12 ft.	Fall=6 ft.
...	...	...	...	...	...	...	„ 1, lock.	
750000	...	...	...	...	...	...	„ 14, 2nd class bridge, 2 spans of 42 ft.	
770000	60	5	1 in 800	1·599	2·09	706	„ 15, 2nd ditto 2 do. of 42 ft.	
790000	...	...	...	...	...	...	„ 16, 2nd ditto 2 do. of 42 ft.	
806000	...	...	...	...	...	...	„ 3, escape, 11 spans of 6 ft.	
...	...	...	...	...	...	...	„ 3, escape fall, 6 do. of 12 ft.	Fall=10 ft.
810000	...	...	...	...	...	...	„ 17, 1st class bridge, 2 spans of 42 ft.	
830000	...	...	...	...	...	...	„ 18, 2nd ditto 2 do. of 42 ft.	
850000	60	...	1 in 8000	1·599	2·09	706	„ 19, 2nd ditto 2 do. of 42 ft.	
870000	...	...	...	...	...	...	„ 20, 2nd ditto 2 do. of 42 ft.	
892000	57	5	1 in 8000	1·599	2·09	673	„ 2, bridge and fall, 6 bays of 12 ft.	Fall=6 ft.
...	...	...	...	...	...	...	„ 2, lock.	
900000	...	...	...	...	...	...	„ 21, 2nd class bridge, 2 spans of 40 ft.	
920000	...	...	...	...	...	...	„ 22, 2nd ditto 2 do. of 40 ft.	

940000	...	...	...	...	...	...	...	„ 23, 2nd ditto 2 do. of 40 ft.	
950000	...	...	...	...	...	...	...	„ 24, 2nd ditto 2 do. of 40 ft.	
970000	...	...	...	...	...	...	...	„ 25, 2nd ditto 2 do. of 40 ft.	
990000	53	5	1 in 8000	1·584	2·07		628	„ 26, 2nd ditto 2 do. of 40 ft.	
1010000	...	...	...	...	...	...	...	„ 27, 1st ditto 2 do. of 38 ft.	
1030000	51	5	1 in 8000	1·584	2·07		605	„ 28, 2nd ditto 2 do. of 38 ft.	
1050000	...	...	...	...	...	...	...	„ 29, 2nd ditto 2 do. of 36 ft.	
1070000	47	5	1 in 8000	1·576	2·06		561	„ 30 2nd class bridge, 2 spans of 36 ft.	
1090000	45	5	1 in 8000	1·569	2·05		549	„ 31 2nd ditto 2 do. of 36 ft.	
1110000	...	...	...	...	...	...	...	„ 32 2nd ditto 2 do. of 36 ft.	
1120000	57	4	1 in 7000	1·546	2·02		511	„ 3 bridge and fall, 5 bays of 12 ft.	Fall=4½ ft.
...	...	...	...	...	...	...		„ 3 lock.	
1128000	...	...	...	...	...	...		„ 4 escape, 10 spans of 6 ft.	
...	...	...	...	...	...	...		„ 4 escape fall, 5 bays of 12 ft.	Fall=10 ft.
1135000	...	...	...	...	...	...	...	„ 33 2nd class bridge, 2 spans of 39 ft.	
1150000	55	4	1 in 7000	1·546	2·02		493	„ 34 2nd ditto 2 do. of 39 ft.	
1170000	53	4	1 in 7000	1·538	2·01		475	„ 35 2nd ditto 2 do. of 39 ft.	
1190000	51	4	1 in 7000	1·538	2·01		459	„ 36 2nd ditto 2 do. of 37 ft.	
1210000	49	4	1 in 7000	1·538	2·01		440	„ 37 1st ditto 2 do. of 37 ft.	
1230000	47	4	1 in 7000	1·530	2·00		422	„ 38 2nd ditto 2 do. of 35 ft.	
1250000	45	4	1 in 7000	1·530	2·00		404	„ 39 2nd ditto 2 do. of 35 ft.	
1270000	43	4	1 in 7000	1·523	1·99		385	„ 40 2nd ditto 2 do. of 35 ft.	
1287000	40	4	1 in 5000	1·515	1·98		358	„ 4 bridge and fall, 3 bays of 12 ft.	Fall=10 ft.
...	...	...	...	...	...	...		„ 4 lock.	
1297000	40	4	1 in 5000	1·515	1·98		358	„ 5 bridge and fall, 3 do. of 12 ft.	do. =10 ft.
1306000	40	4	...	1·515	1·98	...		„ 6 ditto 3 do. of 12 ft.	do. =10 ft.
1306250	40	4	...	1·515	1·98	...		„ 7 ditto 3 do. of 12 ft.	do. =10 ft.
1306500	40	4	...	1·515	1·98	...		„ 8 ditto 3 do. of 12 ft.	do. =10 ft.
1307000 247 miles, 2840 feet.	...	...	...	...	...	...			

APPENDIX C.—(*Continued.*)

Distance from head, in feet.	Width of bottom of channel.	Depth of water.	Slope of bed.	Bottom velocity, in feet per second.	Mean velocity, in feet per second.	Discharge, cubic feet per second calculated.	Description of works.		
				FYZABAD BRANCH.					
				Section No. 1.					
0	112	7	1 in 13000	1·513	1·977	1764	Mina Kote Trifurcation.		
10000	...	...	...	...	...	...	No. 1, 2nd class bridge,	3 spans of 45 ft.	
17000	...	...	...	...	...	...	„ 1, bridge and fall,	10 bays of 12 ft.	Fall=10 ft.
...	...	...	...	...	...	...	„ 1, lock.		
34000	102	7	1 in 10000	1·713	2·238	1763	„ 2, 2nd class bridge,	3 spans of 45 ft.	
52000	...	...	...	...	...	...	„ 2, bridge and fall,	9 bays of 12 ft.	Fall=10 ft.
...	...	...	...	...	...	...	„ 2, lock.		
74000	101	...	...	1·713	2·238	1746	„ 3, bridge and fall,	9 bays of 12 ft.	Fall=10 ft.
...	...	...	...	...	...	...	„ 3, lock.		
90000	...	...	...	...	...	...	„ 4, bridge and fall,	9 bays of 12 ft.	Fall=10 ft.
...	...	...	...	...	...	...	„ 4, lock.		
102000	100	7	...	...	...	1730	„ 3, 2nd class bridge,	3 spans of 42 ft.	
120000	...	7	...	1 713	2·238	1730	„ 5. bridge and fall,	9 bays of 12 ft.	Fall=10 ft.
...	...	...	...	...	...	...	„ 5, lock.		
140000	...	...	...	...	...	...	„ 4, 2nd class bridge,	3 spans of 42 ft.	
163000	...	...	...	...	...	...	„ 6, bridge and fall,	9 bays of 12 ft.	Fall=10 ft.
...	...	...	...	...	...	...	„ 6, lock.		
183000	97	7	1 in 10000	1·711	2·236	1680	„ 7, bridge and fall,	9 bays of 12 ft.	Fall=10 ft.
...	...	...	...	...	...	...	„ 7, lock.		
200000	95	7	1 in 10000	1·710	2·235	1647	„ 5, 2nd class bridge,	3 spans of 42 ft.	
223000	95	7	1 in 10000	1·710	2·235	1647	„ 8, bridge and fall,	9 bays of 12 ft.	Fall=10 ff.
...	...	...	...	...	...	...	„ 8, lock.		

271000	80	6	1 in 8000	1·765	2·306		1232
...	...	...	...	...	...	...	
290000	...	...	...	...	...	...	
...	...	...	...	...	...	...	
395000	77	6	...	1·765	2·306		1173
...	...	...	...	...	...	...	
352000	75	6	...	1·758	2·298		1158
...	...	...	...	...	...	...	
426000	73	6	...	1·755	2·294		1129
...	...	...	...	...	...	...	
482600	66	6	...	1·745	2·280		1016
...	...	...	...	...	...	...	
483000	...	...	...	...	...	...	
91 miles, 2520 feet.							
				SUPPLEMENTARY CHANNEL.			
0							
13000	85	11·5	1 in 12000	1·91	2·50		2945
28000	...	...	...	...	...	...	
43000	...	...	...	...	...	...	
59000	...	...	...	...	...	...	
76000	...	...	...	...	...	...	
89000	...	...	...	...	...	...	
105000	...	...	...	...	...	...	
113000	...	...	...	...	...	...	
116000	...	...	...	...	...	...	
127000	...	...	...	...	...	...	

„ 9, bridge and fall, 7 bays of 12 ft. Fall=10 ft.

„ 9, lock.

„ 1, escape, 14 spans of 6 ft.

„ 1, escape fall, 7 bays of 12 ft. Fall=10 ft.

„ 10, bridge and fall, 7 do. of 12 ft. Fall=7 ft.

„ 10 lock.

„ 11, bridge and fall, 7 do. of 12 ft. Fall=7 ft.

„ 11 lock.

„ 12, bridge and fall, 7 do. of 12 ft. Fall=7 ft.

„ 12, lock.

„ 13, bridge and fall, 6 do. of 12 ft. Fall=10 ft.

„ 13, lock,

Bifurcation, escape, and supply channel at Uncha Khera.

Regulating bridge and lock, Fyzabad Branch, 16 bays of 6 ft.
Ditto ditto ditto, Lucknow ditto, 6 do. of 6 ft.
Ditto ditto ditto, at head of escape channel, 23 do. of 6 ft.

Regulating dam across the Sardah at Delaha, 1200 ft long.
Head of Supplementary channel, Regulating bridge, 17 ft. spans of 6 ft.

Lock, and Protective embankments, &c.

No. 1, 2nd class bridge, 3 spans of 33 ft.

„ 2, 2nd ditto 3 do. of 33 ft.

„ 3, 2nd ditto 3 do. of 33 ft.

„ 4, 2nd ditto 3 do. of 33 ft.

Syphon for the river Ool, 5 do. of 30 ft.

No. 5, 2nd class bridge, 3 do. of 33 ft.

„ 6, 2nd ditto 3 do. of 33 ft.

„ 7, 1st ditto 3 do. of 33 ft.

„ 8, 1st ditto 3 do. of 33 ft.

„ 9, 2nd ditto 3 do. of 33 ft.

APPENDIX C.—(*Continued.*)

Distance from head in feet.	Width of bottom of channel.	Depth of water.	Slope of bed.	Bottom velocity, in feet per second.	Mean velocity, in feet per second.	Discharge, cubic feet per second calculated.	Description of works.
				SUPPLEMENTARY CHANNEL.—(Continued.)			
134000	85	1·15	1 in 12000	1·91	2·50	2945	No. 10, 2nd class bridge, 3 spans of 33 ft.
144000	...	...	...	...	...	...	„ 11, 2nd ditto 3 do. of 33 ft.
159000	...	...	...	...	...	...	„ 12, 2nd ditto 3 do. of 33 ft.
175000	...	...	...	...	...	...	„ 13, 2nd ditto 3 do. of 33 ft.
189000	...	...	...	...	...	...	„ 14, 2nd ditto 3 do. of 33 ft.
199000	...	...	...	...	...	...	„ 15, 2nd ditto 3 do. of 33 it.
210000	...	...	...	...	...	...	„ 16, 2nd ditto 3 do. of 33 ft.
218000	...	...	...	...	...	...	„ 17, 1st class bridge, 3 spans of 33 ft.
219000	...	...	...	...	...	...	Bifurcation at Uncha Khera.
41 miles 2520 feet.							
				FYZABAD BRANCH. *Section No. 2.*			
0	100	10	1 in 13000	1·76	2·30	2639	Bifurcation at Uncha Khera.
14000	...	...	...	...	...	...	No. 1, 1st class bridge, 3 spans of 33 ft.
26000	...	...	...	...	...	...	„ 1, bridge and fall, 9 bays of 12 ft. Fall=10 ft.
...	...	...	...	...	...	...	„ 1 lock.
40000	100	9	1 in 10000	1·92	2·51	2554	„ 2, 2nd class bridge, 3 spans of 33 ft.
45000	...	...	...	...	...	...	„ 3, 2nd ditto 3 do. of 33 ft.
70000	...	...	...	...	...	...	„ 4, 1st ditto 3 do. of 33 ft.
85000	...	...	...	...	...	...	„ 5, 2nd ditto 3 do. of 33 ft.
99000	...	...	...	...	...	...	„ 2, bridge and fall, 9 bays of 12 ft. Fall=10 ft.
...	...	9	1 in 10000	...	2·51	...	„ 2, lock.
115000	96	9	1 in 10000	1·91	2·50	2483	„ 6, 2nd class bridge, 3 spans of 36 ft.
130000	...	...	...	...	...	...	„ 7, 1st ditto 3 do. of 36 ft.

145000	...	...	...	...	...	...		,, 8, 2nd ditto	3 do. of 36 ft.	
160000	...	..	...	...	...	...		,, 9, 2nd ditto	3 do. of 36 ft.	
169000	...	...	...	...	...	...		,, 3, Bridge and fall,	9 bays of 12 ft.	Fall=10 ft.
...	...	...	...	...	...	...		,, 3, lock.		
185000	94	9	1 in 10000	1·91	2·50		2411	,, 10, 1st class bridge,	3 spans of 36 ft.	
200000	94	9	1 in 10000	1·91	2·50	...		,, 11, 2nd ditto	3 do. of 36 ft.	
215000	...	...	...	...	...	...		,, 12, 2nd ditto	3 do. of 36 ft.	
230000	...	...	...	...	...	...		,, 13, 1st ditto	3 do. of 36 ft.	
244000	...	...	...	...	...	...		,, 4, bridge and fall,	9 bays of 12 ft.	Fall=10 ft.
...	...	...	...	...	...	...		,, 4, lock.		
260000	92	9	...	1·91	2·50		2340	,, 14, 2nd class bridge,	3 spans of 34 ft.	
275000	...	...	...	...	...	...		,, 15, 2nd ditto	3 do. of 34 ft.	
290000	...	...	...	...	...	...		,, 16, 1st ditto	3 do. of 34 ft.	
305000	...	...	...	...	...	...		,, 17, 2nd ditto	3 do. of 34 ft.	
320000	...	...	...	..	...	...		,, 18, 2nd ditto	3 do. of 34 ft.	
334000	...	...	...	...	...	...		,, 5, bridge and fall,	9 bays of 12 ft.	Fall=10ft.
...	...	...	...	...	...	...		,, 5, lock.		
350000	90	9	...	1·91	2·50		2292	,, 19, 2nd class bridge,	3 spans of 34 ft.	
365000	...	...	...	...	...	...		,, 20, 1st ditto	3 do. of 34 ft.	
380000	...	...	...	...	...	...		,, 21, 2nd ditto	3 do. of 34 ft.	
394000	...	...	...	...	...	...		,, 22, 1st ditto	3 do. of 34 ft.	
404000	...	...	...	...	...	...		Bifurcation and escape at Durriabad.		
								Head of No. 3 Escape Channel,	17 bays of 6 ft.	
								Head of Jounpoor Branch,	9 bays of 6 ft.	
...	...	...	...	...	...	...		Head of Fyzabad Branch,	8 bays of 6 ft.	
...	...	...	...	...	...	...		No. 3 Escape fall,	9 bays of 12 ft.	Fall=10 ft.
76 miles 2720 feet.										
				Section No. 3.						
0	36	9	1 in 9000	1·852	2·42		1079	Bifurcation at Durriabad.		
10000	...	...	...	...	...	...		No. 1, 2nd class bridge,	1 span of 49½ ft.	
18000	...	...	...	...	...	...		,, 1, bridge and fall,	4 bays of 12 ft.	Fall=10 ft.

APPENDIX.—(*Continued.*)

Distance from head in feet.	Width of bottom of channel.	Depth of water.	Slope of bed.	Bottom velocity, in feet per second.	Mean velocity, in feet per second.	Discharge, cubic feet per second calculated.	Description of works.
				FYZABAD BRANCH.			
				Section 3.—*(Continued.)*			
...	...	...	...	...	...	...	No. 1, lock.
36000	76	6	1 in 10000	1·576	2·06	1049	„ 2, 2nd class bridge, 2 spans of 42 ft.
50000	...	...	...	...	...	...	„ 3, 2nd ditto. 2 do. of 42 ft.
56000	74	6	...	1·576	2·06	1023	„ 4, 2nd ditto 2 do. of 42 ft.
80000	...	...	...	...	...	...	„ 5, 2nd ditto 2 do. of 42 ft.
96000	72	6	...	1·569	2·05	983	„ 6, 2nd ditto 2 do. of 42 ft.
110000	...	...	...	...	...	...	„ 7, 2nd ditto 2 do. of 42 ft.
125000	70	6	...	1·569	2·05	970	„ 8, 2nd ditto 2 do. of 38 ft.
140000	68	6	...	1·569	2·05	943	„ 9, 2nd ditto 2 do. of 38 ft.
155000	67	6	...	1·569	2·05	930	„ 10, 2nd ditto 2 do. of 38 ft.
170000	66	6	...	1·569	2·05	917	„ 11, 2nd ditto 2 do. of 38 ft.
175000	...	...	...	...	...	...	„ 12, 1st ditto 2 do. of 38 ft.
179000	...	...	...	...	...	...	Bifurcation at Pahargunge.
...	...	...	...	...	...	...	Head of the Fyzabad Branch and No. 2 fall.
179000	66	6	1 in 10000	1·959	2·05	917	Head of the Azimgurh Branch, 8 spans of 6 ft. Fall=10 ft.
184000	22	3	1 in 3000	1·569	2·56	203	„ 13, 1st class bridge, 1 do. of 26½ ft
189000	...	...	...	...	...	...	„ 14, 1st ditto 1 do. of 26½ ft.
194000	...	...	...	...	...	...	„ 15, 1st ditto 1 do. of 26½ ft.
200000	...	...	...	...	...	...	„ 16, 1st ditto 1 do. of 26½ ft.
208000	...	...	...	..	...	...	„ 3, bridge and fall, 2 bays of 12 ft. Fall=10 ft.
...	...	...	...	...	...	...	„ 3, lock.
39 miles, 2080 feet.							

LUCKNOW BRANCH.

0	52	5	1 in 8000	1·584	2·07	616	Bifurcation at Uncha Khera,
10000	...	...	...	...	...	...	No. 1, 1st class bridge, 2 spans of 37 ft.
16000	...	...	...	...	...	...	,, 1, bridge and fall. 5 bays of 12 ft. Fall=7 ft.
...	...	...	...	...	...	...	,, 1, lock.
30000	50	5	...	1·584	2·07	594	,, 2, 2nd class bridge, 2 spans of 37 ft.
50000	...	...	...	...	...	...	,, 3, 1st ditto 2 do. of 37 ft.
70000	...	...	...	...	...	...	,, 4, 2nd ditto 2 do. of 37 ft.
86000	48	5	...	1·576	2·06	572	,, 5, 2nd ditto 2 do. of 36 ft.
100000	...	...	...	...	...	...	,, 6, 2nd ditto 2 do. of 36 ft.
115000	46	5	...	1·576	2·06	549	,, 7, 2nd ditto 2 do. of 34 ft.
130000	...	...	...	...	...	...	,, 8, 2nd ditto 2 do. of 34 ft.
150000	44	5	...	1·569	2·05	528	,, 9, 1st ditto 2 do. of 34 ft.
170000	42	5	...	1·561	2·04	506	,, 10, 2nd ditto 2 do. of 34 ft.
192000	40	5	...	1·561	2·04	484	,, 2, bridge and fall, 4 bays of 12 ft. Fall=7 ft.
...	...	...	...	...	...	...	,, 2, lock.
207000	47	4	1 in 7000	1·530	2	422	,, 11, 2nd class bridge, 2 spans of 33 ft.
220000	...	...	...	...	...	...	,, 3, bridge and fall, 5 bays of 12 ft. Fall=7 ft.
...	...	...	...	...	...	...	,, 3, lock.
234000	43	4	...	1·523	1·99	385	,, 12, 2nd class bridge, 2 spans of 33 ft.
246000	...	...	...	...	...	...	,, 13, 2nd ditto 2 do. of 33 ft.
262000	...	...	...	...	...	...	,, 4, bridge and fall, 4 bays of 12 ft. Fall=10 ft.
...	...	...	...	...	...	...	,, 4, lock.
272000	45	3	in 7000	1·454	1·90	281	,, 14, 2nd class bridge, 2 spans of 33 ft.
282000	...	...	...	...	...	...	,, 15, 1st ditto 2 do. of 33 ft.
293000	...	...	...	...	...	...	,, 5, bridge and fall, 4 bays of 12 ft. Fall=10 ft.
...	...	...	...	...	...	...	,, 5, lock.
294000	...	...	...	...	...	...	,, 6, bridge and fall, 4 bays of 12 ft. Fall=7 ft.
...	...	...	...	...	...	...	,, 6, lock.
297000	...	...	...	...	...	...	Goomtee river.
56 miles, 1320 feet.							

APPENDIX C.—(*Continued.*)

Distance from head in feet.	Width of bottom of channel.	Depth of water.	Slope of bed.	Bottom velocity, in feet per second.	Mean velocity, in feet per second.	Discharge, cubic feet per second calculated.	Description of works.
				DURIABAD AND JOUNPORE BRANCH.			
...	45	9	1 in 10000	1·798	2·35	1236	Bifurcation at Duriabad, Regulating bridge and lock. 9 spans of 6 ft.
20000	...	...	...	...	...	...	No. 1, 2nd class bridge, 2 spans of 29 ft.
40000	44	9	...	1·791	2·34	1212	„ 2, 1st ditto 2 do. of 29 ft.
60000	43	9	...	1·791	2·34	1189	„ 1, bridge and fall, 4 bays of 12 ft. Fall=7 ft.
...	...	...	...	...	...	...	„ 1, lock.
75000	75	6	...	1·576	2·06	1036	„ 3, 1st class bridge, 2 spans of 42 ft.
90000	...	...	...	...	...	...	„ 4, 2nd ditto 2 do. of 42 ft.
105000	...	...	...	...	...	...	„ 5, 2nd ditto 2 do. of 42 st.
120000	...	...	...	...	...	...	„ 6, 2nd ditto 2 do. of 42 ft.
135000	...	...	...	...	...	...	„ 7, 2nd ditto 2 do. of 42 ft.
150000	...	...	...	...	...	...	„ 8, 2nd ditto 2 do. of 42 ft.
170000	...	...	...	...	...	...	„ 9, 2nd ditto 2 do. of 42 ft.
190000	74	6	...	1·576	2·06	1023	„ 10, 2nd ditto 2 do. of 42 ft.
210000	73	6	...	1·576	2·06	1010	„ 11, 2nd ditto 2 do. of 42 ft.
230000	72	6	...	1·569	2·05	996	„ 2, bridge and fall, 7 bays of 12 ft. Fall=6 ft.
...	...	...	...	...	...	...	„ 2, lock.
250000	71	6	...	1·569	2·05	983	„ 12, 2nd class bridge, 2 spans of 42 ft.
270000	70	6	1 in 10000	1·569	2·05	970	„ 13, 2nd ditto 2 do. Of 38 ft.
290000	68	6	...	1·569	2·05	943	„ 14, 2nd ditto 2 do. of 38 ft.
300000	67	6	...	1·569	2·05	930	„ 3, bridge and fall, 6 bays of 12 ft. Fall=3 ft.
...	...	...	...	...	...	...	„ 3, lock.
320000	65	5	1 in 8000	1·607	2·10	762	„ 15, 2nd class bridge, 2 spans of 38 ft.
340000	62	5	...	1·599	2·09	729	„ 16, 2nd ditto 2 do. of 38 ft.

360000	60	5	1 in 8000	1·599	2·09	706	„ 17, 2nd ditto	2 do. of 32 ft.
380000	57	5	...	1·592	2·08	673	„ 18, 1st ditto	2 do. of 32 ft.
400000	55	5	...	1·592	2·08	650	„ 19, 2nd ditto	2 do. of 32 ft.
420000	52	5	...	1·584	2·07	616	„ 20, 2nd ditto	2 do. of 32 ft.
440000	50	5	...	1·584	2·07	594	„ 21, 2nd ditto	2 do. of 32 ft.
460000	47	5	...	1·576	2·06	561	„ 22, 2nd ditto	2 do. of 27 ft.
480000	45	5	...	1·569	2·05	539	„ 23, 2nd ditto	2 do. of 27 ft.
500000	42	5	...	1·561	2·04	506	„ 24, 2nd ditto	2 d0. of 27 ft.
520000	40	5	...	1·561	2·04	484	„ 25, 1st ditto	2 do. of 27 ft.
542000	37	5	1 in 5000	1·546	2·02	451	„ 4, bridge and fall,	4 bays of 12 ft. Fall=10 ft.
...	...	...	...	...	...	...	„ 4, lock.	
553000	22	3	...	1·959	2·56	203	„ 26, 1st class bridge,	1 spans of 26½ ft.
567000	...	...	...	...	...	...	„ 5, bridge and fall,	2 bays of 12 ft. Fall=10 ft.
...	...	...	...	...	...	...	„ 5, lock	
571000	...	...	...	...	...	...	„ 6, bridge, and fall,	2 bays of 12 ft. Fall=10 ft.
...	...	...	...	...	...	...	„ 6, lock.	
571500	...	...	...	...	...	...	„ 7, bridge and fall,	2 do. of 12 ft. ditto.
...	...	...	...	...	...	...	„ 7, lock.	
572000	...	...	...	...	...	...	„ 8, bridge and fall,	2 do. of 12 ft. ditto.
...	...	...	...	...	...	...	„ 8, lock.	
108 miles, 1760 feet.								

AZIMGURH BRANCH.

							Pahargunge Bifurcation. Regulating bridge and fall,	8 spans of 6 ft.
...	...	...	...	...	...	...	No. 1, bridge and fall,	6 bays of 12 ft. Fall=7 ft.
20000	60	5	1 in 8000	1·599	2·09	706	„ 1, 2nd class bridge,	2 spans of 32 ft.
40000	57	5	...	1·599	2·09	673	„ 2, 2nd ditto	2 do. of 32 ft.
60000	55	5	...	1·592	2·08	650	„ 3, 2nd ditto	2 do. of 32 ft.
80000	52	5	...	1·584	2·07	616	„ 4, 2nd ditto	2 do. of 32 ft.
100000	50	5	...	1·584	2·07	594	„ 5, 2nd ditto	2 do. of 32 ft.

APPENDIX C.—(*Continued.*)

Distance from head in feet.	Width of bottom of channel.	Depth of water.	Slope of bed.	Bottom velocity, in feet per second.	Mean velocity, in feet per second.	Discharge, cubic feet per second calculated.	Description of works.
				AZIMGURH BRANCH.—(*Continued.*)			
120000	48	5	1 in 8000	1·576	2·06	572	No. 2, bridge and contracted fall, bay of 18½ ft. Fall=7 ft.
135000	48	4	1 in 7000	1·530	2·00	431	„ 6, 2nd class bridge, 2 spans of 27 ft.
150000	...	...	...	...	...	...	„ 7, 2nd ditto 2 do. of 27 ft.
170000	...	...	...	...	...	...	„ 8, 2nd ditto 2 do. of 27 ft.
185000	...	...	...	...	...	...	„ 9, 2nd ditto 2 do. of 27 ft.
200000	...	...	...	...	...	...	„ 10, 2nd ditto 2 do. of 27 ft.
220000	...	...	...	...	...	...	„ 11, 2nd ditto 2 do. of 27 ft.
240000	45	4	...	1·530	2·00	404	„ 12, 2nd ditto 2 do. of 27 ft.
260000	42	4	...	1·523	1·99	376	„ 13, 2nd ditto 2 do. of 27 ft.
280000	39	4	...	1·515	1·98	348	„ 14, 2nd ditto 1 span of 44 ft.
300000	36	4	...	1·515	1·98	322	„ 15, 2nd ditto 1 do. of 44 ft.
320000	32	4	...	1·507	1·97	286	„ 16, 2nd ditto 1 do. of 35 ft.
340000	29	4	...	1·50	1·96	259	„ 17, 2nd ditto 1 do. of 35 ft.
360000	26	4	...	1·50	1·96	232	„ 18, 2nd ditto 1 do. of 35 ft.
380000	23	4	...	1·49	1·95	205	„ 19, 2nd ditto 1 do. of 35 ft.
400000	20	4	...	1·49	1·94	178	„ 3, bridge and contracted fall 1 bay of 7½ ft. Fall=4 ft.
420000	12	3	1 in 5000	4·423	1·86	93	„ 20, 1st class bridge, 1 span of 14½ ft.
430000	10	...	...	1·41	1·84	80	„ 21, 1st ditto 1 do. of 14½ ft.
440000	...	...	...	...	...	...	„ 22, 1st ditto 1 do. of 14½ ft.
445000	...	...	...	...	...	...	„ 4, bridge and contracted fall, 1 bay of 4 ft. Fall=10 ft.
450000	...	...	...	...	...	...	„ 5, ditto ditto 1 do. of 4 ft. ditto.
450800	...	...	...	...	...	...	„ 6, ditto ditto 1 do. of 4 ft. ditto.
450600	...	...	...	...	...	...	„ 7, ditto ditto 1 do. of 4 ft. ditto.
85 miles, 2200 feet.							

ABSTRACT OF LENGTH.

		Miles.	Feet.	Miles.	Feet.
Main Channel,	Supply Channel from Bunbassa to Kunjah Bojh,	7	3040		
	Canal from Kunjah Bojh to Mina Kote Trifurcation,	13	3924	21	1684
Branches,	Shahjehanpoor Branch from Mina Kote to Shahjehanpoor,	63	1360		
	Benares Branch from Mina Kote to Benares,	359	4480		
	Lucknow and Jounpoor Branch from Sisoree Bifurcation to Jounpoor,	247	2840		
	Supplementary Channel from Delaha to Uncha Khera,	41	2520		
	Fyzabad Branch from Mina Kote to Fyzabad,	207	2040		
	Lucknow Branch from Uncha Khera to Lucknow,	56	1320		
	Durriabad and Jounpoor Branch from Durriabad to Jounpoor,	108	1760		
	Azimgurh Branch from Fyzabad to Azimgurh,	85	2200	1169	2680
Escape Channels,	Escape Channel at Mina Kote,	2	4440		
	Do. do. at Sisoree,	1	2720		
	Do. do. at Burona,	...	3500		
	Do. do. at Bela Khariah,	...	4500		
	Do. do. at Saraon,	2	3440		
	Do. do. at Pyra,	...	2300		
	Do. do. at Lucknow,	...	1000		
	Do. do. at Tiloee,	1	720		
	Do. do. at Bardih,	2	940		
	Do. do. at Uncha Kheree,	1	2720		
	Do. do. at Chand Kaon,	...	4000		
	Do. do. at Russulpoor,	...	3500	15	2100
	Grand Total,	...	...	1206	1184

APPENDIX D.

SARDAH CANAL.

STATEMENT OF LAND REQUIRED.

Canal Line.	Length in feet.	Width in feet.	Total in acres.	Grand Total.
CENTRAL LINE.				
From Kunjah Bojh to Mina Kote, ...	7,25,670	..	2,001	
Escape Channel, ...	14,000	500	161	
4 Chokie Compounds, 4 acres each, ...	..	..	16	2,178
SHAHJEHANPOOR BRANCH.				
Mina Kete to Shahjehanpoor, ...	3,34,000	100	767	
Rajbuhas, ...	..	..	1,008	
6 Chokee compounds, ...	..	..	18	1,793
BENARES BRANCH.				
Section No. 1, ...	3,07,000	600	4,229	
Do. „ 1 escape, ...	8,000	420	78	
Do. „ 2, ...	5,64,000	550	7,121	
Do. „ 2 escape, ...	3,500	340	27	
Do. „ 3, ...	5,86,000	380	5,112	
Do. „ 3 escapes, ...	4,500	340	35	
	14,000	320	103	
Do. „ 4, ...	4,42,000	250	2,537	
Rajbuhas, ...	..	..	7,518	
26 Lock Channels and enclosures, 66½ acres each, ..	..	..	1,729	
30 Chokie Compounds, 3 acres each, ...	..	..	90	28,579
LUCKNOW AND JOUNPOOR BRANCH.				
Section No. 1, ...	5,43,000	270	3,366	
Do. „ 1 escapes, ...	2,300	320	24	
	1,000	320		
Do. „ 2, ...	7,73,000	260	4,614	
Do. „ 2 escapes, ...	6,000	300	120	
	11,500			
Rajbuhas, ...	..	..	3,171	
16 Lock Channels and enclosures, at 66½ acres each,	..	..	1,064	
21 Chokie Compounds, ...	..	..	63	12,422
Carried over, ..	..	..	..	44,972

APPENDIX D.—*(Continued.)*

Canal Line.	Length in feet.	Width in feet.	Total in acres.	Grand Total.
Brought forward ..				44,972
FYZABAD BRANCH.				
Section No. 1, ...	4,83,000	300	3,327	
Do. „ 1 escapes, ...	4,000	320	30	
Do. „ 1, „	8,000	380	69	
Supplement Channel, ...	2,19,000	320	1,609	
Section No. 2, ...	4,64,000	550	5,101	
Do. „ 2 escapes, ...	3,500	320	26	
Do. „ 3, ...	2,08,000	260	1,239	
Rajbuhas, ...	..	..	4,354	
21 Lock Channels, ...	..	..	1,397	
20 Chokie Compounds, ...	..	..	..	
8 Ditto ditto, at 4 acres each, ...	..	..	32	
12 Ditto ditto, at 3 acres each	..	..	36	17,220
LUCKNOW BRANCH.				
Uncha Kheree to Lucknow, ...	2,97,000	270	1,841	
Rajbuhas, ...	..	..	1,183	
6 Lock Channels, ...	..	..	399	
3 Chokie Compounds, ...	..	..	15	3,438
DURIABAD AND JOUNPOOR BRANCH.				
Duriabad to Jounpoor, ...	5,72,000	260	3,414	
Rajbuhas, ...	..	..	2,268	
9 Chokie Compounds, ...	..	..	27	
8 Lock Channels and enclosures, ...	..	..	532	6,241
AZIMGHUR BRANCH.				
Fyzabad to Azimgurh, ...	4,51,000	130	1,346	
Rajbuhas, ...	..	..	1,596	
7 Chokie Compounds, ...	..	..	21	2,963
GRAND TOTAL ACRES, ..	..	..	..	74,834

APPENDIX E.

AVAILABLE HORSE POWER.

Statement showing the effective power for mechanical purposes available in each of the Districts traversed by the Sardah Canal.

District.	Number of fall.	Height. Feet.	Discharges.	H. P.	Total in each District.
SHAHJEHANPOOR BRANCH.					
Bareilly, ...	1	7	351	162	
„	2	„	340	157	
„	3	10	300	198	
„	4	5	290	96	
„	5	7	280	129	
„	6	5	180	59	
„	7	„	112	37	
„	8	„	93	31	869
Shahjehanpoor, ...	9	„	56	18	
„	10	10	36	24	
„	11	20	36	48	90
BENARES BRANCH.					
Section No. 1.					
Bareilly, ...	1	10	4,894	3,230	
„	2	„	4,867	3,212	
„	3	„	4,818	3,180	
„	4	„	4,818	3,180	
„	5	„	4,768	3,148	
„	6	„	4,546	3,000	
„	7	„	4,546	3,000	
„	8	„	4,500	2,970	24,920
Shahjehanpoor, ...	9	„	4,408	2,909	
„	10	„	4,305	2,841	5,750
Kheree, ...	11	„	4,259	2,811	
„ Section No. 2, ...	1	10	2,340	1,544	4,355
Section No. 2.					
Hurdui, ...	2	10	2,292	1,513	
„	3	6	2,147	850	2,363
Oonao, ...	4	10	2,005	1,323	
„	5	„	1,884	1,243	
Section No. 3.					
Oonao, ...	1	10	1,762	1,163	3,729
Pertabgurh,...	2	6	1,432	567	567
Allahabad, ...	3	8	1,390	277	
Section No. 4.					
Allahabad, ...	1	8	639	127	404
Benares, ...	2	10	330	218	

APPENDIX E.—*(Continued).*

District.	Number of fall.	Height. Feet.	Discharges.	H. P.	Total in each District.
BENARES BRANCH.—(*Continued.*)					
Benares, ...	3	10	281	185	
„	4	„	281	185	
„	5	„	281	185	
„	6	„	281	185	
„	7	„	281	185	1,143
LUCKNOW AND JOUNPOOR BRANCH.					
Section No. 1.					
Hurdui, ...	1	6	1,803	714	
„	2	„	1,762	698	
„	3	„	1,761	697	
„	4	„	1,680	665	
„	5	„	1,597	632	
„	6	„	1,548	613	4,019
Lucknow, ...	7	10	1,383	913	
„	8	„	1,301	859	
Section No. 2.					
Lucknow, ...	1	6	970	384	2,156
Sultanpoor,...	2	„	706	280	280
Pertabgurh, ...	3	4½	549	154	154
Jounpoor, ...	4	10	385	254	
„	5	„	358	236	
„	6	„	358	236	
„	7	„	358	236	
„	8	„	358	236	1,198
FYZABAD BRANCH.					
Section No. 1.					
Bareilly, ...	1	10	1,764	1,164	
„	2	„	1,763	1,164	
„	3	„	1,746	1,152	
„	4	„	1,746	1,152	4,632
Shahjehanpoor, ...	5	„	1,730	1,141	
„	6	„	1,730	1,141	2,282
Kheree, ...	7	„	1,680	1,109	
„	8	„	1,646	1,086	
„	9	„	1,232	813	
„	10	7	1,173	542	
„	11	„	1,158	535	
„	12	„	1,129	521	
„	13	10	1,016	670	

APPENDIX E.—(*Continued.*)

District.	Number of fall.	Height. Feet.	Discharges.	H. P.	Total in each District.
FYZABAD BRANCH.—(*Continued.*)					
Section No. 2.					
Kheree, ...	1	10	2,639	1,742	
„	2	„	2,554	1,686	
„	3	„	2,483	1,639	10,343
Barabunkee, ...	4	„	2,411	1,591	
„	5	„	2,340	1,544	
Section No. 3.					
Barabunkee, ...	1	10	1,079	712	3,847
Fyzabad, ...	2	„	917	605	
„	3	„	203	133	738
LUCKNOW BRANCH.					
Seetapoor, ...	1	7	616	285	
„	2	„	484	224	509
Lucknow, ...	3	„	422	195	
„	4	10	385	254	
„	5	„	281	185	
„	6	7	281	130	764
DURIABAD AND JOUNPOOR BRANCH.					
Barabunkee, ...	1	7	1,189	549	549
Fyzabad, ...	2	6	996	394	
„	3	3	930	184	578
Jounpoor, ...	4	10	451	298	
„	5	„	203	134	
„	6	„	203	134	
„	7	„	203	134	
„	8	„	203	134	834
AZIMGHUR BRANCH.					
Fyzabad, ...	1	7	706	326	
„	2	„	572	264	590
Jounpoor, ...	3	4	178	47	
„	4	10	80	53	
„	5	„	80	53	
„	6	„	80	53	
„	7	„	80	53	257

APPENDIX E.—(*Continued.*)

General Abstract of H. P. at falls in each District.

Districts.	Shahjehanpoor branch.	Benares branch.	Lucknow and Jounpoor Branch.	Fyzabad branch.	Lucknow branch	Duriabad and Jounpoor branch.	Azimgurh Branch.	Total Horse Power.
Bareilly, ...	869	24,920	...	4,632	...	...	...	30,421
Shahjehanpoor,... ...	90	5,750	...	2,282	...	...	...	8,122
Kheree,...	...	4,355	...	10,343	...	...	...	14,698
Hurdui, ...	...	2,363	4,019	...	...	...	...	6,382
Seetapoor, ...	...	...	...	...	509	...	...	509
Oonao, ...	...	3,729	...	...	...	...	...	3,729
Lucknow, ...	...	...	2,156	...	764	...	...	2,920
Barabunkee, ...	...	...	...	3,847	...	549	...	4,396
Fyzabad, ...	...	...	...	738	...	578	590	1,906
Sultanpoor	...	...	280	...	...	...	...	280
Pertabgurh, ...	...	567	154	...	...	...	...	721
Allahabad, ...	...	404	...	...	...	...	...	404
Jounpoor, ...	...	...	1,198	...	...	834	259	2,291
Benares, ...	...	1,143	...	...	...	...	...	1,143
Total ...	959	43,231	7,807	21,842	1,273	1,961	849	77,922

APPENDIX F.

SARDAH CANAL.

Abstract of Rates.

Description.	Rates adopted.		Rates in Oudh.	
	Rate.	Per.	Rate.	Per.
CHANNEL EXCAVATION.				
Main Channel, ...	2-13 to 9-13	1,000 c. ft.		
Branches, ...	2-4 to 4-12	Do.		
Lock Channels, ...	2-4	Do.		
Escape Channels, ...	3-8	Do.		
Widening at Falls, Bridges, &c., ...	3-8	Do.		
River Diversions, ...	4-0 to 7-0	Do.		
Turfing, ...	0-4-0 to 0-5-0	100 s. ft.		
Fencing, ...	3-0	100 r. ft.		
Concrete Walls, ...	125-0	1,000 c. ft.		
Clearance of Jungle, ...	75-0 to 80-0	acre.		
Compensation for Lands, ...	20-0	acre.		
MASONRY WORKS.				
Excavation for foundations, ...	4-0	1,000 c. ft.		
Ditto in shingle and boulder, ...	6-0	1,000 do.		
Boulder Masonry, ...	14-0 to 15-0	100 do.		
Ditto packing, ...	7-0	100 do.		
Boulder and kunkur flooring, ...	6-0	Do. do.		
Concrete, ...	8-0	Do. do.		
Pucka brickwork, ...	25-0	Do. do.		
Ditto ditto in wells, ...	20-0	Do. do.		
Ditto ditto in arches, ...	28-0	Do. do.		
Brick on edge flooring.	28-0	Do. do.		
Hammer dressed ashlar, ...	1-12	cubic foot		
Stone, ...	2-0	Do.		
Stone grooving, ...	2-0	lineal foot		
WELL SINKING.				
Cylinders, 16 ft. diameter, ...	30-0	running foot.		
Ditto 14 ft. ditto, ...	22-0	Do.		
Ditto 12 ft. ditto, ...	20-0	Do.		
Ditto 10 ft. ditto, ...	18-0	Do.		
Ditto 8 ft. ditto, ...	17-0	Do.		
Ditto 7 ft. ditto, ...	15-0	Do.		
Puddling, ...	10-0	1,000 c. ft.		
Metalling, ...	5-0	100 do.	4 to 5	100 c. ft.
Iron railing, 2½ in height, ...	5-0	running foot.		
Sal woodwork, ...	3-0	c. ft.		
Ditto Lock gates, ...	7-8	Do.		
Ditto Sluice gates, ...	4-8	Do.		
Ditto Sleepers	15-0	each		
Ditto ditto for rails, ...	3-8	c ft.		
Drum sluices, ...	130 to 150	each.		
Hooks, ...	12-0	Do.		
Pulleys for lock gearing, ...	5-8 to 6-0	Do.		
Chain for ditto, ...	1-0	linl. ft.		
Crabs, ...	140 to 150	each.		
Travelling crane, ...	300-0	Do.		
Tramway rails, ...	18 0	maund.		
Ditto spikes, ...	25-0	Do		
Cast Iron, ...	14-0	Do.		
CHOWKIES.				
Pucka brickwork, ...	21-0	100 c. ft.	20-0	
Kutcha pucka brickwork, ...	14-0	Do.	14-0	
Kutcha brickwork, ...	3-0	Do.	3-0	
Woodwork, ...	3-0	c. ft.	3-0	
Brick flooring, ...	15-0	100 c. ft.	15-0	
Terrace roofing, ...	18-0	100 s. ft.	18-0	
Plastering, ...	3-0	100 s. ft.	3-0	
Whitewashing, ...	0-4	Do.	0-4-0	
Plinth Filling, ...	0-4	100 c, ft.	Do.	
Panelled and glazed doors and windows, ...	1-0	s. ft.	1-0-0	
Batten doors, ...	0-8	Do.	0-8-0	
Iron railings, ...	12-0	maund		
Sunshades, ...	0-12	s. ft.	0-12-0	

APPENDIX G.

BENCH MARKS.

Bench marks.	Sardah Canal Levels.	G. T. S. Levels.	Difference.	Remarks.
434th Milestone, Grand Trunk Road near Benares,	265·37	265·37		G. T. Survey. Heights N. W. P. and Bengal, page 28.
Bridge No. 52, O. R. Ry., ...	404·95			
Culvert No. 54, ...	402·60	403·28	·68H.	G. T. S. Oudh, page 55.
Temple, Kakaji, ...	397·40	398·08	·68H.	Ditto.
Well, Chotain Sirdar, ...	383·40	{ 384·12 / 383·56 }	·72H.	Ditto.
Culvert No. 34, ...	398·41	399·11	·70H.	Ditto.
Well, Banthara, ...	400·40	401·10	·70H.	Ditto.
Culvert No. 26, ...	398·68	399·38	·70H.	Ditto.
Alum Bagh, ...	403·47	{ 404·17 / 409·21 }	·70H.	Ditto.
Tank, Futteh Ali, ...	399·46	400·15	·69H.	Ditto.
Iron Bridge, Lucknow, ...	371·93	{ 372·42 / 371·924 }	·49H.	Ditto.
G. T. B. M. Ataria, ...	418·37	418·49		Page 52.
Uncha Khera, ...	453·41			
Seetapoor, ...	445·51	{ 445·87 / 445·538 }	·36H.	Page 50.
Luckeempoor No. 3, ...	483·68			
Sunnea No. 24, ...	461·48			
Delaha No. 28, ...	476·12			
Trifurcation, ...	629·82			
Pillibheet, ...	609·69	{ 609·82 / 609·82 }	·13H.	Page 42.

Note by Superintendent, Great Trigonometrical Survey of India.

The height above the mean sea level of Karachi Harbour, of the G. T. S. Bench mark at Cawnpore, as brought down directly from the B. M. at Meerut, by the main line of levels, is—

407·75 feet.

(Vide page 12 of tables of heights in North Western Provinces and Bengal.)

The height as brought down from Meerut, by the branch line through Moradabad, Bareilly, Shahjehanpoor, and Lucknow, is—

407·11 feet.

Thus the two determinations differ by 0·64 feet, which cannot be considered a material discrepancy, for the two lines are of the respective lengths of 290 and 330 miles, forming a circuit of 620 miles.

As the heights on the main line, as well as those on the branch line as far as Bareilly, have already been published, it is not at present desirable to alter them, though this will have to be done eventually. As a provisional measure, the discrepancy of 0·64 feet has been distributed over the levels between Bareilly Church and the B. M. at Cawnpore, the argument being the distance in miles from Bareilly.

N. B.—The large black figures denote levels furnished by Mr. Lane, Great Trigonometrical Survey.

APPENDIX H.

Average rainfall in the districts traversed by the Sardah Canal (approximate.)

District.	Fall in inches per annum.
Pillibheet, ...	55·1
Bareilly, ...	41·76
Shahjehanpoor, ...	36·46
Kheree, ...	27·31 } doubtful.
Hurdui, ...	19·47 }
Seetapoor, ...	35·51
Oonao, ...	25·87
Lucknow, ...	36·03
Barabunkee, ...	34·46
Fyzabad, ...	44·50
Roy Bareilly, ...	31·32
Sultanpoor, ...	38·10
Pertabgurh, ...	40·65
Allahabad, ...	42·80
Jounpoor, ...	43·52
Azimgurh, ...	43·65
Benares, ...	40·10

APPENDIX I.

Project by Sir Arthur Cotton and Colonel Rundall, for the Irrigation of Oudh.

EAST INDIA IRRIGATION AND CANAL COMPANY.

Received under cover of Secretary to Chief Commissioner, Oudh, D. P. W., No. 1210, dated 25th August 1868.

General outline statement of the scheme of works projected on behalf of this Company for supplying Irrigation and Navigation to the Province of Oudh, and for connecting that province, by means of the "Soane Project," with Calcutta, and now under consideration by the Directors.

It is necessary to commence this paper with the remark, that the description it purports to give of the several contemplated main lines of canal and works is founded upon a general local survey and plan by Major General Sir Arthur Cotton and Colonel Rundall, two Engineer Officers of the largest experience in the projection of such works, and that, although such description cannot be more than an approximate one, still subject to those alterations which may be shown by a close and detailed examination to be advisable and necessary, it may be assumed to represent fairly a general outline of the scheme desired to be undertaken.

It is also right to add, that the Directors, after long and very careful consideration, have the strongest conviction that too much importance cannot possibly be attached to the connexion of the system of works now proposed to be provided for Oudh, with that intended for Behar, &c., seeing that, thereby, each portion of the territories occupied by both schemes will be united by cheap and easy lines of water communication with every other portion, and become possessed of all those advantages which flow from a general interchange of commodities and produce, whilst the agricultural and commercial capabilities of the whole of the area thus combined will be rendered capable of full development by the provision of an external post and direct communication with the markets of the world. The effect of thus uniting the two schemes upon the pecuniary interests of the Company will unquestionably be very great and satisfactory, as the profits realized from each portion of the undertaking will be materially increased, but the benefits that will at the same time be conferred upon the Government and upon the people will be immeasurably more extensive.

The scheme of works thus planned for Oudh, with reference to their connexion with the Behar project may be described as follows:—

At a point on the Sardah river, about thirty miles below Barumdeo, it is proposed to construct an anicut, or weir, across that river, from immediately above which a main trunk canal (Main Trunk Canal No. 1) will be carried close past the towns of Pillibheet and Bareilly, and be continued from thence southwards, as presently described.

It may, and probably will, be found, upon a more detailed investigation, to be inadvisable to bring the whole of the required water for this "Main Trunk Canal No. 1" from so high a point on the Sardah as Barumdeo, in which case, a second anicut will be constructed across that river

considerably below the first anicut, probably near to Beira, and a main supply channel (Main Trunk Canal No. 2) will be led off from thence and be made to deliver its water into "Main Trunk Canal No. 1" a little south of Shahjehanpoor, which "Main Trunk Canal No. 1," will then be continued near to the Ganges river? (the highest ground being there) to opposite Allahabad, where it can be connected with the system of works projected for Behar, from the Soane, &c., by an aqueduct across the Ganges, which aqueduct has been proposed to form part of the last mentioned system of works, the cost being borne equally by both projects.

From "Main Trunk Canal No. 1," there may be thrown off one branch (Main Branch Canal No. 1) from below Oonao to Cawnpore and another branch (Main Branch Canal No. 2) to Lucknow, and then on to the Gogra above Fyzabad, or the "Main Trunk Canal No. 1" may be divided at a point higher up than Oonao, *i. e.*. near to Sandeela, one division or line (Main Trunk Canal No. 2) passing Lucknow and proceeding parallel with the Goomtee to Benares, the other division or line (Main Trunk Canal No. 1) proceeding direct to Cawnpore as before stated.

The "Main Trunk Canal No. 1" and its branches (Branch Canals Nos. 1 and 2) or its division (Main Trunk Canals Nos. 2 and 1) will provide for the irrigation of the whole tract of country between the Ganges and the Goomtee, and also the means of communication between Rohilkund and the cities of Allahabad and Benares, and by means of the proposed works in Behar, from the river Soane all those places will be connected with Calcutta, whilst the cross channels (Main Branch Canals Nos. 1 and 2) will serve chiefly for navigation to convey the traffic of the present Ganges Canal from Cawnpore to Lucknow, Fyzabad, &c.

At Mularpoor, near to the junction of the river Ghagi or Sardah with the river Gogra, there will be constructed an anicut or weir across the stream, and from the western end of that weir a main trunk channel (Main Trunk Canal No. 3) will be led off to the northern side of Lucknow to meet the "Main Branch Canal No. 2" or the "Main Trunk Canal No. 2," such a weir and canal being required to convey a large portion of the Gogra water over the Goomtee river to assist in irrigating the lands west of that stream, the area between the Gogra and the Goomtee being insufficient in extent to utilize the whole of the Gogra water.

From near Mullarpoor, a main trunk channel (Main Trunk Canal No. 4) will be taken off, from "Main Trunk Canal No. 3" and will be carried parallel with Gogra to the mouth of that river, from which channel the land between the Goomtee and the Gogra will be irrigated.

A connecting channel (Main Trunk Canal No. 1 continuation) will be carried from the "Main Trunk Canal No. 1" past Benares to the end of the "Main Trunk Canal No. 4," at the mouth of the Gogra, to accommodate and connect the very populous tract lying along the north bank of the Ganges with the great cities of Allahabad, Benares and Ghazeepoor, &c., and, by a connexion with Behar or Soane lines of navigation, with Calcutta.

The Cawnpore Branch, or Division of the "Main Trunk Canal No. 1," *i. e.*, "Main Branch Canal No. 1," or "Main Trunk Canal No. 1," may be carried across the Ganges by an aqueduct at Cawnpore and be continued (Main Trunk Canal No. 5) to Allahabad without interfering with the Ganges Canal, except that the latter work would, of course, be connected with, and the navigation be continued along, such "Main Trunk Canal No. 5" to Allahabad, &c. The adoption of this last described work has not been definitely determined upon, but if, after further investigation, it is, as in all probability will be the case, considered advantageous, it will be adopted, and a portion of the water conveyed by it will be made available for irrigation between Cawnpore and Allahabad, whilst the aqueduct across the Jumna at Allahabad (before referred to) to connect the Canal with the Behar or Soane system of works will render the communication with Calcutta complete.

It is also proposed to lead off a channel (Main Trunk Canal No. 6) from the eastern side of the anicut, below Mullarpore, and to carry it past the towns of Baraich, Goruckpoor and Muzufferpoor (in Tirhoot), to the Ganges opposite to Monghyr. This Main Trunk Canal No. 6 will, for most of its length, be carried on watersheds, and will cross comparatively little drainage. It will open up a very large tract of the finest country, and when connected with the aqueduct projected for construction across the Ganges at Monghyr, as part of the Behar or Soane scheme of works, will bring the whole of that tract into direct communication, by the Behar line of Canal, with Calcutta, and will also thus be the means whereby a vast amount of additional traffic will be introduced upon the last mentioned line of Canal. The cost of aqueduct now referred to should, like that of the similar work at Allahabad, be borne by the two schemes equally.

The "Main Trunk Canal No. 4" will also be continued (Main Trunk Canal No. 4 extension) along the north side of the Ganges, and be made to fall into the "Main Trunk Canal No. 6" either some miles above its termination, opposite to Monghyr, or close to that termination. This, it is believed, will be a very inexpensive, but beneficial Canal, and will greatly increase the traffic on the other lines.

From each of the Main Trunk and Main Branch Canals, before described, there will be taken off minor branch channels in every direction, necessary to irrigate the whole of the lands commanded, many of which minor channels will be so constructed as to form connecting and interior lines of navigation.

The leading points in the project, of which the foregoing is a general outline, may be said to be a total absence of engineering difficulties, and of special works requiring in themselves a large or disproportionate outlay, and also unusual natural facilities for carrying it out. It is, in truth, an *eminently practicable* undertaking, possessing special points of recommendation, of which the extraordinary supply of water in the dry season, three times that of the Ganges at Hurdwar, is one, and the peculiar adaptability of climate for European residence possessed by the locality is another. It is, indeed, patent that nothing but works of the nature now proposed, connected with Behar and Calcutta, are wanting to produce a very rapid development.

It has not escaped notice that parts of the scheme now outlined will probably make less direct returns than others, but it has been likewise felt that those parts cannot be omitted without materially affecting the returns to be derived from the whole scheme, and of reducing its public utility, as every individual portion of navigation will greatly affect the general use of the whole system of Canals; and so, with respect to the irrigation proposed, for wherever a weir may be constructed, it would be manifestly false economy not to distribute every drop of the water of which that structure will give the command.

It is necessary, though a repetition, to state, in conclusion, that the desired and proposed connexion between the scheme of works now under review, and that planned from the Soane river, is essential for the Province of Oudh, and will materially benefit the Soane project; and further, that without such connexion both schemes of works will be undeveloped and injuriously effected, whilst great public benefits will be withheld. The Directors of this Company are therefore fully justified in viewing that connexion as an essential element of their own success, and as pre-emminently desirable, on public grounds, and they submit respectfully that to effect that object with economy and efficiency, it is necessary that the details of both schemes should be prepared simultaneously and under the same professional Superintendent.

APPEN

PROVINCE

TABLE

Classification of

	Classification of Lands.		Lucknow Division.			Khyrabad Division.		
			Lucknow.	Oonao.	Bara-bunkee.	Seetapoor.	Hurdui.	Kheree.
			Acres.	Acres.	Acres.	Acres.	Acres.	Acres.
A.	Total area		890,629	863,480	823,012	1,419,031	1,467,114	1,863,930
A.	B.—Barren		199,051	190,697	139,600	210,845	202,405	185,480
	C.—Residue cultivable...		691,578	672,783	683,412	1,208,186	1,264,709	1,678,450
C.	D.—Jagheer, or not paying revenue		41,918	14,504	44,152	7,753	67,991	356,829
	E.—Cultivable, not cultivated		199,978	205,820	97,730	284,139	352,167	555,487
	F.—Fallows of one year		25,467	47,798	9,153	93,406	34,783	71,865
	G.—Crop of one year ...	Rubbee ...	265,371	225,274	372,863	406,891	465,179	306,054
		Khurreef ...	158,844	179,387	159,514	415,997	344,589	388,415
		Total ...	424,215	404,661	532,377	822,888	809,768	694,469
G.	H.—Baranee, or not irrigated	Rubbee ...	120,161	104,109	233,840	253,048	260,284	228,978
		Khurreef ..	112,650	118,699	149,770	392,981	292,241	374,357
		Total ...	232,811	222,808	383,610	646,029	552,525	603,335
	Cultivated irrigated.							
	I.—By canal...	Rubbee ...	...	...	...	...	...	...
		Khurreef ...	...	...	...	...	...	...
		Total ...	...	...	...	...	...	...
	J.—By jheels or tanks ...	Rubbee ...	94,643	30,255	86,505	104,561	96,566	23,334
		Khurreef ...	25,874	23,250	6,043	...	15,482	2,516
		Total ...	120,517	53,505	92,548	104,561	112,048	25,850
	J.—By streams	Rubbee ...	9,684	11,710	2,665	6,749	18,490	9,334
		Khurreef ...	4,024	9,658	...	...	3,006	...
		Total ...	13,708	21,368	2,665	6,749	21,496	9,334
	J.—By wells.	Rubbee ...	40,883	79,200	49,853	42,533	89,839	44,408
		Khurreef ...	16,296	27,780	3,701	23,016	33,860	11,542
		Total ...	57,179	106,980	53,554	65,549	123,699	55,950
	I & J.—Total irrigated ...	Rubbee ...	145,210	121,165	1,39,023	153,843	204,895	77,076
		Khureef ...	46,194	60,688	9,744	23,016	52,348	14,058
		Total ...	191,404	181,853	148,767	176,859	257,243	91,134
			No.	No.	No.	No.	No.	No.
	Population	Town ...	304,072	25,983	70,282	73,546	94,430	51,185
		Rural ...	697,547	675,741	781,506	737,740	850,809	570,894
		Total ...	1,001,619	701,724	851,788	811,286	945,239	622,079

Abstract of areas

	Rubbee.
	Acres.
Baranee	2,002,558
Canal	1,58,149
Other irrigation	1,993,930
Total crop	4,154,637
Fallow	...
Total ...	

Superintending Engineer's Office,
Lucknow 7th March, 1870.

DIX J.

OF OUDH.

I.

Lands and Crops for the year 1868-69.

Fyzabad Division.			Roy Bareilly Division.			Total.
Fyzabad.	Gondah.	Baraich.	Roy Bareilly.	Sultanpoor.	Pertabgurh.	
Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.
1,492,749	1,717,120	1,451,048	861,927	1,004,843	1,103,144	14,958,027
407,389	171,712	166,579	201,744	307,246	458,277	2,841,025
1,085,360	1,545,408	1,284,469	660,183	697,597	644,867	12,117,002
29,258	152,495	18,055	29,267	24,084	13,962	800,068
236,174	248,166	500,412	202,797	180,190	67,072	3,130,132
9,647	114,474	74,758	5,983	4,900	32,124	524,358
521,558	406,323	402,793	202,252	249,296	330,783	4,154,637
288,723	623,950	288,451	219,884	239,127	200,926	3,507,807
810,281	1,030,273	691,244	422,136	488,423	531,709	7,662,444
143,198	131,584	365,774	37,625	48,023	75,934	2,002,558
208,768	469,409	286,917	75,887	57,814	60,308	2,599,801
351,966	600,993	652,691	113,512	105,837	136,242	4,602,359
...	...	...	...	...	158,149	158,149
...	...	...	...	...	61,808	61,808
...	...	...	...	...	219,957	219,957
218,297	137,369	26,764	68,881	32,590	85,695	1,005,460
41,857	...	223	92,399	164,761	71,807	444,212
260,154	137,369	26,987	161,280	197,351	157,502	1,449,672
9,449	...	...	1,000	4,101	11,005	84,187
1,723	147,852	...	1,500	...	7,003	174,766
11,172	147,852	...	2,500	4,101	18,008	258,953
150,614	137,370	10,255	94,746	164,582	...	904,283
36,375	6,689	1,311	50,098	16,552	...	227,220
186,989	144,059	11,566	144,844	181,134	...	1,131,503
378,360	274,739	37,019	164,627	201,271	254,849	2,152,079
79,955	154,541	1,534	143,997	181,313	140,618	908,006
458,315	429,280	38,553	308,624	382.586	395,467	3,060,085
No.	No.	No.	No.	No.	No.	No.
64,900	61,308	18,889	17,573	33,872	3,758	819,798
1,368,672	1,104,061	770,547	765,044	899,900	937,707	10,160,158
1,433,572	1,165,359	789,436	782,617	933,772	941,465	10,979,956

in acres.

Khurreef.	Total.
Acres.	Acres.
2,599,801	4,602,359
61,808	219,957
846,198	2,840,128
3,507,807	7,662,444
...	524,358
Cultivated.	8,186,802

J. G. FORBES, *Captain, R. E.,*
Offg. Supdg. Eng., Sardah Canal, Oudh.

APPENDIX J.—(*Continued.*)

PROVINCE OF OUDH.

TABLE II.

Distribution of Crops for the year 1868-69.

Distribution of Crops.	Lucknow Division.			Khyrabad Division.			Fyzabad Division.			Roy Bareilly Division.			Total.
	Lucknow.	Oonao.	Barabunkee.	Seetapore.	Hurdui	Kheree.	Fyzabad.	Gondah.	Baraich.	Roy Bareilly.	Sultanpoor.	Pertabgurh.	
	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.
Khureef. Rice	29,973	16,560	63,805	39,897	20,644	103,527	110,333	370,896	96,479	124,174	201,233	103,070	1,280,591
Cotton	1,074	2,590	345	2,431	19,843	5,425	...	1,446	2,265	2,043	5,854	1,773	45,089
Indigo	50	351	8	3	532	...	289	101	6	100	200	2,563	4,203
Tobacco	930	985	675	5,427	3,344	11,038	8,832	802	655	1,150	6,261	5,392	35,491
Indian Corn, Jowar, and Bajra	62,363	144,020	11,875	117,206	169,335	72,590	5,503	114,234	72,766	73,358	4,200	52,585	900,045
Oil-Seeds	52	2,492	347	5,975	507	5,455	708	2,892	21,097	2,395	765	...	42,685
Miscellaneous	52,082	3,996	72,090	222,249	105,805	191,982	108,776	126,347	91,428	12,694	10,323	21,652	1,019,424
Total	146,524	170,994	149,145	393,188	320,010	380,017	234,441	616,718	284,706	215,914	228,836	187,035	3,327,528
Rubee. Wheat and Barley	140,965	171,930	135,457	259,602	333,341	167,937	162,558	180,266	171,691	167,553	148,092	230,590	2,269,982
Gram and Pulses	70,525	41,717	98,535	118,185	53,047	20,874	109,807	51,513	99,340	20,270	44,508	90,285	818,606
Oil-Seeds	10,981	6,740	27,815	22,696	4,809	7,799	18,417	3,616	9,834	2,089	133	500	115,429
Poppy	745	382	3,230	761	2,316	...	13,517	10,849	231	200	5,111	672	38,014
Miscellaneous	39,268	3,385	105,867	5,369	65,972	91,664	208,831	158,633	113,936	10,290	48,247	4,161	855,623
Total	262,484	224,154	370,904	406,613	459,485	288,274	513,130	404,877	395,032	200,402	246,091	326,208	4,097,654
Two Fusl Crops. Sugar	9,081	6,687	9,847	15,457	22,385	15,834	50,242	5,786	3,209	2,600	8,056	9,939	159,123
Vegetables & fruits, Khurreef	3,239	1,706	522	7,352	2,194	3,726	4,040	1,446	305	1,370	2,235	3,952	32,087
,, ,, Rubbee	2,887	1,120	1,959	278	5,694	6,618	8,428	1,446	7,992	1,850	3,205	4,575	46,052
Total	15,207	9,513	12,328	23,087	30,273	26,178	62,710	8,678	11,506	5,820	13,496	18,466	237,262
Grand Total	424,215	404,661	532,377	822,888	809,768	694,469	810,281	1,030,273	691,244	422,136	488,423	531,709	7,662,444

Offg. Supdg. Engineer's Office,
Lucknow, 7th March 1871.

J. G. FORBES, *Captain, R. E.,*
Offg. Supdg. Engineer, Sardah Canal, Oudh

APPENDIX J.—*(Continued.)*

PROVINCE OF OUDH.

TABLE III.

Weight of Produce in Maunds for the Year 1868-69.

Nature of produce.	Total.		Lucknow Division.			Khyrabad Division.			Fyzabad Division.			Roy Bareilly Division.		
	Area.	Weight.	Lucknow.	Oonao.	Bara-bunkee.	Seetapoor.	Hurdui.	Kheree.	Fyzabad.	Gondah.	Baraich.	Roy Bareilly.	Sultanpoor.	Pertabgurh.
Rice	1,280,591	12,089,668	261,363	37,050	470,262	916,346	206,440	1,035,270	862,811	3,262,872	1,254,227	2,370,166	1,658,721	754,140
Cotton	45,089	73,152	3,397	604	417	4,533	39,686	8,136	26	850	5,662	3,493	3,512	2,836
Sugar	159,123	1,874,759	162,111	44,997	98,223	381,493	402,930	91,452	326,857	86,790	67,090	50,400	64,448	97,968
Indigo	4,203	1,655	16	81	2	3	1,108	...	51	38	...	6	...	350
Tobacco	35,491	352,233	7,160	7,325	13,748	68,162	23,408	6,228	78,187	4,010	5,178	10,050	47,583	81,194
Indian corn, jowar and bajra	900,045	7,080,908	559,870	587,880	107,184	495,048	1,088,173	362,945	161,180	1,599,276	582,408	1,198,804	23,355	314,785
Wheat and barley	2,269,982	23,926,731	1,665,643	1,028,580	1,490,988	2,706,638	3,413,410	1,442,687	1,656,096	1,847,724	1,321,089	2,571,384	1,308,436	2,474,056
Gram and pulses	818,606	4,789,521	640,486	162,435	332,688	991,099	190,071	258,868	351,960	618,156	496,700	111,478	285,927	349,653
Poppy	38,014	81,676	136	1,089	16,240	172	7,238	...	589	54,245	231	101	1,500	135
Vegetables and fruits	78,139	1,286,555	251,416	52,872	136,117	25,921	270,680	70,237	282,862	65,070	...	17,531	58,336	55,513
Oil-seeds	158,114	638,188	82,195	51,094	34,733	114,993	13,290	33,135	45,421	19,524	93,537	38,291	458	161,467
Miscellaneous	1,875,047	10,776,388	589,880	19,752	642,154	1,464,666	602,110	1,281,744	777,692	3,666,294	876,080	100,788	591,281	163,947
Total, ...	7,662,444	62,971,384	4,173,673	1,993,759	3,342,756	7,169,074	6,258,544	4,590,702	4,543,732	11,224,849	4,702,202	6,472,492	4,043,557	4,456,044

OFFG. SUPDG. ENGR'S OFFICE,
LUCKNOW,
7th March 1870.

J. G. FORBES, *Captain, R. E.,*
Offg. Supdg. Engr., Sardah Canals, Oudh.

APPENDIX J.—(*Continued.*)

PROVINCE OF OUDH.

TABLE IV.

Distribution of Produce in maunds for the year 1868-69.

Exports.		Rice.	Cotton.	Sugar.	Indigo.	Indian corn, Jowar and Bajra.	Wheat and Barley.	Gram and Pulses.	Poppy.	Vegetables and Fruits.	Oil Seeds.	Tobacco	Miscellaneous.	Total.
Lucknow Division ...	Lucknow	1,31,182	2,403	91,056	940	1,55,175	11,33,332	4,04,043	...	49,400	22,087	4,230	1,45,840	21,39,688
	Oonao	6,720	...	16,200	51	1,85,925	1,97,530	71,000	650	600	15,969	1,265	2,000	4,97,910
	Barabunkee ...	2,37,585	...	50,152	...	57,424	6,94,234	1,20,000	8,900	98,000	12,375	11,700	2,42,407	15,32,777
Khyrabad ,, ...	Seetapoor	25,695	1,10,165	14,175	...	2,00,615	3,36,929	3,68,153	34	2,10,975	1,42,500	2,100	3,16,224	17,27,565
	Hurdui	9,680	...	...	...	2,02,376	5,41,532	4,55,840	...	...	90,732	...	1,91,015	14,91,175
	Kheree	58,439	2,208	...	...	44,497	82,666	59,158	...	...	3,418	5,200	1,39,497	3,95,083
Fyzabad ,, ...	Fyzabad	36,500	...	1,56,857	51	...	3,32,281	53,000	...	589	20,421	6,000	2,11,850	8,17,549
	Gondah	1,96,178	...	21,697	...	3,61,776	1,22,242	59,412	30,156	15,018	5,412	60	2,53,910	10,65,861
	Baraich	2,26,012	166	43,634	...	2,42,516	5,46,561	1,59,830	...	...	40,027	4,193	4,20,549	16,83,488
Roy Bareilly ,, ...	Roy Bareilly	51,055	...	18,714	...	1,46,388	1,56,450	...	97	...	5,682	1,000	20,906	4,00,292
	Sultanpoor	10,96,010	38,984	51,517	...	25,000	2,15,500	25,000	1,120	4,776	24,000	1,023	29,500	15,12,430
	Pertabgurh ...	2,53,290	105	59,200	349	1,10,315	10,53,042	1,55,712	110	17,087	44,855	27,823	60,575	17,82,463
	Total	23,28,346	1,54,031	5,23,202	1,391	17,32,007	54,12,299	19,31,148	41,067	3,96,445	4,27,478	64,594	20,34,273	1,50,46,281

Kept for Consumption.		Rice.	Cotton.	Sugar.	Indigo.	Indian corn, Jowar and Bajra.	Wheat and Barley.	Gram and Pulses.	Poppy.	Vegetables and Fruits.	Oil Seeds.	Tobacco.	Miscellaneous.	Total.
Lucknow Division ...	Lucknow	1,30,182	1,008	71,056	520	1,04,695	5,32,332	2,02,043	136	2,02,016	10,087	3,430	1,44,040	14,01,540
	Oonao	30,330	604	28,797	30	4,01,955	8,31,050	91,435	439	52,272	35,125	6,060	17,752	14,95,849
	Barabunkee ...	2,32,677	417	48,070	2	49,759	7,96,753	2,12,687	7,339	38,116	12,357	2,048	3,99,747	17,99,973
Khyrabad ,, ...	Seetapoor	6,04,635	1,28,575	1,89,295	12	5,92,071	13,75,181	4,98,957	13	5,75,735	4,68,958	1,68,950	6,59,131	52,61,513
	Hurdui	1,30,800	10,600	...	...	7,38,000	31,23,000	16,15,255	...	...	3,86,200	...	5,49,725	65,53,580
	Kheree	9,76,831	5,928	91,452	...	3,18,448	13,60,021	1,99,710	...	70,237	29,717	1,028	11,42,247	41,95,619
Fyzabad ,, ...	Fyzabad	8,26,311	26	1,70,000	...	1,61,180	13,23,815	2,98,960	...	2,82,862	25,000	72,187	5,65,842	37,26,183
	Gondah	30,66,694	850	65,093	38	12,37,500	19,15,482	5,58,744	24,089	50,052	14,112	3,950	34,12,384	1,03,48,988
	Baraich	10,28,215	5,496	23,456	...	3,39,892	7,74,528	3,36,870	231	...	53,510	985	4,55,531	30,18,714
Roy Bareilly ,, ...	Roy Bareilly... ...	23,19,111	3,493	31,686	6	10,52,416	24,14,934	1,11,478	4	17,531	32,609	9,050	79,882	60,72,200
	Sultanpoor	3,50,615	16,528	1,03,931	11	1,96,055	13,97,936	2,60,927	380	58,560	48,270	49,110	6,71,521	31,53,844
	Pertabgurh ...	5 00,850	2,731	38,768	1	2,04,470	14,21,014	1,93,941	25	38,426	1,16,612	53,371	1,03,372	26,73,581
	Total	1,01,97,251	1,76,251	8,61,604	620	53,96,441	1,72,66,046	45.81,007	32,656	13,85,807	12,32,557	3,70,169	82,01,174	4,97,01,583

OFFG. SUPDG. ENGR'S OFFICE,
LUCKNOW
7th March 1870.

J. G. FORBES, *Captain R. E.*
Offg. Supdg. Engr., Sardah Canals, Oudh.

APPENDIX J.—(*Continued.*)

Name of district.	Gross area. acres.	Cultivated area. acres.	Barren area. acres.	Cultivable area. acres.	P. C. of cultivated to gross area.	Irrigated area.	P. C. of irrigated to cultivated area.	P. C. of irrigated to gross area.	P. C. irrigated by wells and streams to cultivated.
Bareilly, ...	.....	.....	.....	Unknown.	...	...	...	...	...
Shahjehanpoor, ...	.....	.....	.....	„	...	.....	...	9	...
Hurdui, ...	14,67,114	8,09,768	2,02,405	12,64,709	55	2,57,243	32	18	18
Oonao, ...	8,63,480	4,04,661	1,90,697	6,72,783	47	1,81,853	45	21	32
Roy Bareilly, ...	8,61,927	4,22,136	2,01,744	6,60,183	49	3,08,624	73	36	35
Pertabgurh, ...	11,03,144	5,31,709	4,58,277	6,44,867	48	3,95,467	74	36	45
Lucknow, ...	8,90,629	4,24,215	1,99,051	6,91,578	47	1,91,404	45	21	17
Sultanpoor, ...	10,04,843	4,88,423	3,07,246	6,97,597	49	3,82,586	78	38	38
Kheree, ...	18,63,930	6,94,469	1,85,480	16,78,450	37	91,134	13	5	9
Seetapoor, ...	14,19,031	8,22,888	2,10,845	12,08,186	58	1,76,859	21	12	9
Barabunkee, ...	8,23,012	5,32,377	1,39,600	6,83,412	65	1,48,767	28	18	11
Fyzabad, ...	14,92,749	8,10,281	4,07,389	10,85,360	54	4,58,315	57	31	24
Allahabad, ...									
Benares, ...									
Jounpoor, ...									
Azimgurh, ...	.....	.....	.....	Unknown.	...	...	...	...	
Ghazeepoor, ...									
Gorruckpoor, ...									

APPENDIX K.

Expenditure on the Sardah Canals from 1867-68, to 1st September 1870.

	Expenditure up to 31st March 1870.	Expenditure from 31st March 1870 up to 1st September 1870.	Total.
Canal Chowkies, ...	12,299	..	12,299
Bench Marks, ...	2,356	96	2,452
Wells, ...	2,727	..	2,727
Tools and Plant, ...	5,430	231	5,661
Purchase and keep of Elephants,..	8,365	986	9,351
Clearing jungle, lock spitting, &c., ...	7,387	69	7,456
Taking Discharges,..	41	..	41
Survey Establishments, ...	4,840	874	5,714
Cost of providing supplies for survey establishment, ...	945	..	945
Survey Contingencies, and Dâk Runners, ...	574	920	1,494
Salaries of Establishment,..	1,03,341	30,500	1,33,841
Travelling Allowances, ...	13,739	4,254	17,993
Contingencies, ...	2,967	1,417	4,384
Total, Rs ..	1,65,011	39,347	2,04,358

APPENDIX L.

SARDAH CANAL.

General Report by Captain J. G. Forbes, R. E., Superintendent of Irrigation Works, Oudh, on a Proposed Canal for the Irrigation of Oudh, and a portion of the North-Western Provinces—dated 10th February 1869.

In a memorandum on irrigation in Oudh, dated 29th June 1867, the Chief Commissioner, Mr. Strachey, stated that the portion of the province most urgently requiring canal irrigation was situated to the north-west of an imaginary line running from the Ganges at Cawnpore to the Gogra, at Fyzabad. The tract of country to the south-east of this line, owing to the proximity to the surface of the level of springs, and its facilities for the construction of wells, was not in such pressing need of canal water. With the view of irrigating this portion of Oudh, as well as the ground lying east of the river Deoha, in Rohilkund, Mr. Strachey suggested the advisability of taking out a canal from the Sardah near Burm Deo, where the river emerges from the hills.

2. This scheme had been previously examined to a certain extent by Lieutenant (now Lieutenant-Colonel) Anderson, of the Madras Engineers, in the cold season of 1856-57. The intervention of the Mutiny had, however, led to the loss of nearly all the papers and field-books connected with the levels taken; but, fortunately, Colonel Anderson was able to preserve his diary, containing many valuable notes and suggestions regarding irrigation in Oudh (an abstract of which is given in Appendix A.), together with sufficient data from which to construct a longitudinal section, showing levels approximately near to the water-shed of the Doab between the Gogra and Goomtee from Burm Deo to Fyzabad.

3. In January 1868, Messrs. Henslowe and Froude, Assistant Engineers, were appointed to assist me in preparing a project for the irrigation of the country alluded to in paragraph 1. Levelling was commenced in February, and the amount of field work done during last season is shown in Appendix B. By the latter end of July 1868 sufficient information had been collected to enable a rough outline of the proposed scheme to be submitted to the Inspector General of Irrigation Works.

Subsequently, it was determined that the benefits of irrigation should be extended beyond the limits of Oudh and Rohilkund to the districts of Azimghur and Jounpoor; and eventually, in September last, I was ordered to take up the question of irrigating the Benares and Ghazeepoor districts also, or the entire doab between the Gogra and Ganges from Futtehgurh to near the junction of the Soane with the latter river; and the northern doab between the rivers Gurha or Deoha and Sardah, a total area of upwards of 20,000 square miles; the details, regarding the natural features, resources, &c., of which will be found in Appendix C., which is an abstract of the answers furnished me by the Deputy Commissioners and Collectors

of districts to the questions enumerated in appendix. The staff of officers in the Irrigation Department of Oudh was also increased by the appointment of Messrs. Heaford and Handcock, Executive Engineers, and Mr. Clarke, Assistant Engineer.

4. On the 12th February 1868, I arrived at Burm Deo, which, on reference to Appendix A., will be seen to be the spot which Colonel Anderson recommended as the proper situation for the head of a canal from the Sardah. The only other site that he mentions, as being favourably situated for the above purpose is at Naik-ka-Goth, a small village, three miles below Burm Deo; but he enters into reasons for preferring the upper position, and concludes with a strong recommendation of Burm Deo. He alludes, however, to Bunbassa (9 miles below Burm Deo) being a good site, and states that "it would be quite practicable to open a canal from this point if a line higher up was unsuitable."

5. After carefully examining the river and taking levels for comparison with those taken by Colonel Anderson in 1857, I am confident that a canal from the Sardah, taken from either Burm Deo or Naik-ka-Goth, would be extremely expensive on account of the very many masonry works which would be required to overcome the excessively steep slope of the country, and to pass the canal across the many intervening torrents and streams; and that the advantages of taking the canal from either of the above sites, which undoubtedly are most favourable in some respects, *viz.*, stability of stream and the proximity of building materials, &c., are not counterbalanced by the great disadvantage they labour under in being situated, respectively 200 and 160 feet above the highest point, Soorae (*vide* paragraph 8), where it is required to deliver water for the irrigation of Oudh and a portion of the North-Western Provinces. This opinion will, I think, also be coincided with by Colonel Anderson, now that a more complete series of levels have been taken of the country to be irrigated than was able to be finished in 1857.

6. Having come to the above conclusion, it was necessary to examine the river lower down in order to determine the proper position for a canal head. Below Naik-ka-Goth, the Sardah splits into several branches, which rejoin in one stream at Bunbassa, where, however, the river again immediately ramifies into numberless channels which do not re-unite until they get to Moondeea Ghát, 13 miles lower down.

The two sites then, Bunbassa and Moondeea Ghát, where the ever-shifting stream had for very many years remained tolerably stable in one channel, would naturally be the best spots for examination.

7. To save time and labour in connecting and comparing the levels taken last year with those taken previously by Colonel Anderson, I have accepted the datum as fixed by him, which is 90·30 feet above a permanent bench-mark at Burm Deo, or 100 feet above the mean cold-weather supply level of the Sardah at the spot where it issues out of the rocky defile above Burm Deo.

8. Turning to sheet No. 2, and sketch map of upper portion of Canal, on which are entered a few of the levels taken last year, it will be observed

that the reduced level of Soorae (at the head of the great Mala swamp), which is the point from which all the water-sheds between the Gogra and Ganges radiate, and the key to the whole country requiring to be irrigated, is 302.

The reduced level of water surface (during the cold weather) in the river at Bunbassa, 16 miles above Soorae, is 241, or 61 feet above the highest spot to be irrigated; whilst the reduced level of Moondeea Ghát, which is 8 miles east, or at right angles to the main line of water-shed below Soorae, is 376, or 74 feet below the spot where the proposed head of irrigation is situated. Bearing in mind that between Bunbassa and Burm Deo, the objections I urged in paragraph 5 against having the head either at Burm Deo or Naik-ka-Goth still held good, the above facts showed that the search for a canal head must be made at Bunbassa, or a few miles below it; for lower than Moondeea Ghát the levels prove that a suitable position for a canal head cannot be found if the irrigation of the thirsty lands of Rohilkund, east of the Deoha, is to be accomplished.

9. I accordingly levelled down from Burm Deo to Bunbassa, along the high road to Chandnee, so as to avoid the great delay that would have been caused by cutting my way through the dense jungle at the foot of the hills, had I followed the course of the river; but from Bunbassa for a distance of 12 miles down the right bank of the Sardah (the left bank being in Nipálese territory), a careful series of levels, following the windings of the stream, were taken by Mr. Froude and myself. Other trial lines down and across the different torrents, and a longitudinal series to Soorae (connecting with Colonel Anderson's levels, with a difference of 0·03 in a circle of 60 miles) were also taken by us, as shown in sheet No. 5.

Bunbassa, as canal head considered.

10. Bunbassa, itself, appeared to me an admirable position for a canal head. The main stream of the river, upwards of 500 feet in width, with an average depth of nearly 5 feet, and with a measured (1st March 1868) discharge of nearly 5,900 cubic feet per second, here impinges on, and for a short distance runs close to, the foot of the Bangur, which at this spot is a perpendicular cliff of boulders and shingle, 30 feet above the cold weather level of the Sardah, and 20 feet above the highest floods. The main stream of the river has from time immemorial remained in this channel, and for upwards of 10 years in this *one* channel only; but last year a small stream had broken out from the main channel of the river, a short distance above the site of the Bunbassa ferry, and rejoined the main branch a mile or two lower down. This small stream being entirely in the Nipálese terriory, I was unable to survey its course, or take accurate measurements of its discharge; however, from observations I made, I estimate it discharges 370 or 400 cubic feet per second—an estimate which I think, can be relied on as a close approximation.

This year, the requisite permission having been obtained from the Nipál Government, this small stream has been surveyed, and its discharge measured. It appears to have increased since last year, as at present there is about 900 cubic feet per second passing down. The levels, however, show that there need be no fear as yet of the main stream taking to this small channel.

11. There will not be any difficulty in closing this small branch and forcing its supply down the main stream below Bunbassa, where the river may then be considered to be in one permanent channel—a considerable advantage in favour of a canal head at the spot. *Bunbassa.* Advantage I.

Another advantage in fixing the canal head here would be the proximity of Bunbassa to the sites of our lime and stone quarries. For, at Burm Deo, there is a sand-stone of a sufficiently compact description to be used in the works; within a few miles of Burm Deo lime is procurable, and I have little doubt but what a more prolonged search than I was able to make last year will enable us to find a good hard lime-stone. A tramway of only ten miles in length from Burm Deo would suffice to bring these materials and the large paving boulders from the river at a reasonable cost to Bunbassa, where also the smaller boulders in the bed of the river could be utilized to a very great extent in building. At Bunbassa there are a few boulders up to 1·5 feet in diameter, but the generality of the stones met with are only 6 inches to 9 inches. Limestone boulders I did not observe anywhere on the river, although I searched for them and offered rewards for their procural. Advantage II.

A third advantage in choosing Bunbassa for the head of a *navigable* canal would be its nearness to Burm Deo, one of the chief markets for hill produce; for here, annually in the cold weather, large numbers of hillmen, Thibetans and Nipálese bring down their supplies of borax, wool, &c., either for sale, or in barter for sugar, and other products of India. A trade of some magnitude *(vide* Appendix D.) therefore, springs up, which undoubtedly would be considerably increased if a cheap means of transport was afforded to merchants for the carriage of their goods to and from Burm Deo. The tramway used for the conveyance of materials during the construction of the canal might, on the completion of the works, be utilized in bringing down merchandize and goods from Burm Deo to Bunbassa, from whence they might be boated down the canal. Advantage III.

12. Leaving out of consideration the fact of the, perhaps, too close contiguity of Bunbassa to the Nipálese boundary, as an objection which applies equally to any possible site that could be chosen on the river Sardah for a canal head, the disadvantages of Bunbassa are,—

1*st.*—The great height, 61 feet, of the position above the spot where water is required to be delivered (*viz.*, Soorae), or 99 feet above Mina Kote, which will entail many and expensive masonry falls, *vide* section sheet No. 3. *Bunbassa as head.* Disadvantage I.

2*nd.*—The passage of the Jugboora and Suneea torrents, the former requiring an aqueduct of 10 spans of 50 feet each, and the latter 3 of 30 feet. Disadvantage II.

3*rd.*—The extreme unhealthiness of Bunbassa. Disadvantage III.

13. These reasons induced me to look for the site of canal head lower than Bunbassa, and I accordingly fixed upon the village of Nuglah, 8 miles below Bunbassa, and just below the junction of the Suneea Nuddee, the last of the affluents of the Sardah on its right bank, as a possible suitable situation. The line of levels down the river (sheet No. 4) show that *Nuglah* as canal head.

the water surface level at this point is 333 or 31 feet *below* Soorae. But by leading out a canal from this spot with a slope of 1 in 10,000 (D= 7·114. V=2·74), we find that the bed runs out to the surface close to Mina Kote, a small village about 12 miles below Soorae, but above the sources of the rivers Goomtee and Sye, and thus commanding the whole of the doab in Oudh, between the Ganges and Gogra, and the portion of Rohilkund to the east of the Kunhout Nuddee. The irrigation of the greater part of Rohilkund between the Kunhout Nuddee and the river Deoha can also be provided for by leading out a branch from the main canal near Mina Kote, crossing the Kunhout by an aqueduct, or else by leading out a branch direct from the point where the canal enters the Bangur (*vide* sheet No. 5) above the head of the Mala swamp, along the true water-shed of the Pillibheet and Shahjehanpoor doab. The cost of this latter scheme will, however, be heavy on account of the deep digging at the head, and irrigation will not commence much above Aunwurrea,— a village about 6 miles north-east of Pillibheet.

Nuglah.
Advantage I.

14. By taking out the main canal from the river at Nuglah, we avoid the disadvantages attaching to Bunbassa, *viz.*, the cost of masonry falls, and two aqueducts across the Jugboora and Sunnea, and the extreme unhealthiness of the upper site ; and only lose about 72 square miles of irrigation, which might possibly be obtained between Soorae and Aunwurrea, which irrigation, especially as the ground is now covered with dense jungle, not likely to be cleared for very many years, is a point scarcely worth mentioning ; and when irrigation is required, it can be provided from the Kukra Nuddee. As regards the healthiness of the position, Nuglah is decidedly better than Bunbassa ; for, from the Sunnea Nuddee to Burm Deo, the climate is so extremely unhealthy that even the fever-proof Tharoos will not live there between April and November, whereas from Mina Kote to Nuglah, the same extreme unhealthiness does not prevail, the villages are *not* deserted during the hot season and rains, and instead of finding a population of nothing but Tharoos ; Passis, Lodhs, and other castes are met with. As cultivation extends, the climate gets healthier, and all accounts agree in stating that it certainly is more salubrious now than it was ten years ago.

Advantage II.
Disadvantage I.

15. In looking at the longitudinal section of the river, sheet No. 4, we find that the slope from Burm Deo to Naik-ka-Goth is 14·80 feet per mile : from Naik-ka-Goth to Bunbassa 14·60 feet per mile ; from Bunbassa to the junction of Jugboora Nuddee it is 11·76 feet per mile, and from the Jugboora to the Sunnea Nuddee 10·55 feet per mile ; but from this spot, or where the proposed Nuglah head will be, *the heavy slope in the river ceases ;* for, from the Sunnea Nuddee to Mela Ghát, the slope of the river suddenly decreases to 4·77 feet per mile, which fact alone would point to Nuglah as a most favourable site for a permanent dam across the river.

16. On referring to the sketch map of the upper portion of the canal (facing page 7) and sheet No. 5, it will be observed that at Bunbassa the river Sardah divides into two main branches, which do not rejoin until they reach Moondeea Ghát. Between these two main branches there are numerous small channels which sub-divide the main island of Chandnee

Choke into a great number of smaller islands, the whole of which are covered with a dense growth of Khyr trees. No dependence can be placed on the river running in the same channel for two consecutive years, but the tendency of the stream is evidently to desert its right (or Nuglah) branch, and to shift over entirely to the Dhukna Bagh, or left branch ; for, 30 years ago, the main stream ran down the Nuglah branch, and at the very spot where the proposed canal head will be, there was a ferry with five boats. Year by year, since the above time, the supply down the Nuglah channel has been slowly but steadily decreasing, until now the whole stream between Bunbassa and Nuglah is fordable everywhere, the water not being more than a foot or two deep, and in many places disappearing entirely.

Nuglah suitable for canal head, and *Bunbassa* for permanent dam.

17. Accepting Nuglah, therefore, as a suitable position for the canal head, in order to turn the water into the Nuglah Channel, the permanent dam or weir across the main stream of the Sardah must still be built at Bunbassa, for the detailed surveys and levels which have been taken this year show unmistakeably that at no other spot than Bunbassa can a dam be built with any due regard to economy, or without risk of failure. These detailed surveys having only just been completed, and not yet mapped, at the present stage I cannot enter into any detailed reasoning as to the *minutiæ* which have led me to the above opinion ; but the following broad facts are patent :

1*st.*—That in the whole distance of 25 miles, from Moondeea Ghát to Burm Deo, Bunbassa is the solitary situation where the river Sardah has ever remained fixed and unchangeable in one main channel.

2*nd.*—That the width of the stream at Bunbassa, confined as it is, on one bank by the high land of the bangur, and by the rapidly sloping ground on its other bank in Nipál, reduces the length of the dam, and its cost, therefore (the depth of the river in the cold weather being only 5 feet), together with the protective works that may have to be constructed, to a minimum.

3*rd.*—That if a dam is constructed across the river anywhere lower than Bunbassa, on account of the rapid widening out of the stream into numerous channels and the receding of the bangur, and the high ground in Nipál from either bank of the river, the length of the numerous dams and protective bunds, &c., will be very great, upwards of three miles, instead of 1,200, or 1,500 feet, as at Bunbassa.

4*th.*—That, if the dam is constructed lower than Bunbassa, not only will the cost be greater on account of the enormous difference in the length, &c., but the risk of failure will be much enhanced by the probability of a change in the course of the main stream of the river, (some distance above the dam, which would be built across the present main channel,) and the possibility of its suddenly taking to one of the present minor channels, across which only a small permanent work, or even an earthen dam might be built, which would then inevitably be breached.

5*th*.—That to prevent the above contingency occurring, the whole of the dam, protective works, and the river for some considerable distance upwards, will have to be most carefully watched during the rainy season, or the very time when the climate is so deadly; and

6*th*.—That the entire dam, protective works, &c., would have to be built in Nipálese territory.

18. Coming, now, to the question of the comparative cost of a canal taking out from the Sardah at Nuglah, and of a canal taking out direct from the river at Bunbassa, instead of utilizing the present Nuglah branch as a supply channel as far as Nuglah, we find that, on comparing the cost of either scheme as far as Mina Kote, the proposed head of irrigation, the difference is in favour of the Nuglah head.

On sheet No. 5, the position of these two lines of canal are marked down; sheets Nos. 3 and 4 show the sections along the proposed lines.

Taking first the Bunbassa, or alternative line, we have, as the approximative estimate for a canal discharging 7,114 cubic feet per second, with a mean velocity not exceeding 3 feet per second, which, with 10 feet depth of water in channel, will give a bottom width of 245 feet, the following result, *viz*.:—

	Rs.
Cost of dam and head-works at Bunbassa	5,50,000
" nine (10 feet) falls between Bunbassa and Mina Kote	9,00,00
Jugboora Aqueduct	8,00,000
Sunneea Do.	1,80,00
325,000,000 cubic feet earth-work, @ Rs. 8 per 1,000	26,00,000
433,000,000 cubic feet earth-work, @ Rs. 6 per 1,000	25,98,000
8,000,000 cubic feet concrete core in embankments, @ Rs. 5 per 100	4,00,000
Seven (double-storied) chaukís @ Rs. 6,000 ...	42,000
Total	80,70,000

For the Nuglah line—

Cost of dam and regulating bridge at Bunbassa	5,00,000
Jugboora waste-weir	1,00,000
Supply Channel	5,00,000
Nuglah dam and regulating bridge	4,00,000
470,597,150 cubic feet earth-work, @ Rs. 10 per 1,000	47,05,970
53,462,800 " " " @ " 8 " 1,000	4,27,694
7,944,600 " concrete core in embankments, @ Rs. 5 per 1,000	3,97,230
Chooka aqueduct	1,15,106
Four (double-storied) chaukis, @ Rs. 6,000	24,000
Total	71,70,000

This estimate, it will be observed, is not a detailed one, but is sufficient to show the relative difference in approximate cost between the two possible lines of canal.

19. The solitary advantage that the alternative or Bunbassa line possesses over the Nuglah line, is the possibility of enabling a channel to be carried to Pillibheet for navigation, and for the irrigation of the 72 square miles of country referred to in paragraph 14.

Sole advantage to be gained by spending 9 lakhs.

On the other hand, by adopting the Nuglah line, the construction of the nine falls required to overcome the slope of the country on the alternative line is not required, and in their place only the regulating bridge and dam at Nuglah, and the waste weir for the Jugboora will have to be built, the materials for which, *viz.*, boulders from the river bed, are actually on the spot, instead of having to be carried 4 or 5 miles to the site of the works, as would be the case on the Bunbassa line. Only one half the time therefore will be required to build the masonry works on the Nuglah line to what will be necessary on the Bunbassa one.

Saving of time on Nuglah scheme.

The section on sheet No. 4 shows that the canal on the Nuglah line enters the bangur with a heavy cutting of 40 feet, which does not run out for 12 miles. The detailed surveys made this year, however, show that it is possible to enter with a cutting of 35 or 36 feet only, which will materially lessen the amount of earth-work, and consequent cost of estimate shown in preceding paragraph. A reference to the levels shown on sheet No. 5 will prove that this deep cutting cannot be avoided; for there is no possibility, except by having very high and enormously expensive embankments, of creeping along the edge of the bangur, and then entering the high land with a moderate digging; but the detailed map, when completed, will show this more clearly.

The admission of the Jugboora and Sunnea torrents into the supply channel of the canal might, on the first glance, be thought disadvantageous. The levels show, however, that without any extra cost, both these torrents may be utilized and turned to account; the Jugboora in *silting up* a large jhíl which exists between it and the Sunnea Nuddee, and the Sunnea Nuddee in *removing* the accumulation of silt which will occur above the regulating bridge of the canal. After the Jugboora has deposited the greater part of its silt in the jhíl, which will take many years to fill up, the extra amount of water that enters the supply channel will be passed away by a waste weir into an old channel which rejoins the Nuglah branch of the river below the site of canal head.

20. Without entering into any more detail, I trust sufficient has been said to prove that Nuglah is indubitably the proper position for the canal head, and Bunbassa the proper site for the permanent dam across the river.

21. As regards the amount of water obtainable from the river Sardah at Bunbassa, there are certain data to go upon, as gauges have been maintained for three years, both at that spot and at Burm Deo, during the months of minimum supply, and from a comparison of these

Supply of water in Sardah.

gauges, and the discharges of the river taken by Lieutenant Anderson in 1857, by Lieutenant Harrison in 1866-67, and by myself last year, the following facts are shown :—

1*st.*—That the river Sardah is at its absolute minimum annually in the month of March.

2*nd.*—That the average daily supply passing down the river at Bunbassa is in,—

	Cubic feet.
February	6,808 per second
March	6,113 „
April	7,100 „
May	8,171 „

Average minimum of three years, 5,786 cubic feet, 1866-67-68.

3*rd.*—That the lowest discharge in 1866 was on 20th March, when it amounted to 5,809 cubic feet per second. In 1867, the lowest discharge was 5,600 cubic feet per second to 4th March.

In January 1869, 4,000 cubic feet.

In 1868, the lowest discharge was 5,800 cubic feet per second on 10th March. This year, however, there is barely 4,000 cubic feet per second passing down the river at Bunbassa at the present time (January). Every account agrees, however, in stating that the river has never fallen so low before, and my own observations show that the spring surface level of water in wells on the high land within a few miles of the river is from 4½ to 5 feet lower this year than last. The extreme lowness of the river may, therefore, I think, be fairly looked upon as entirely exceptional, especially when we take into consideration the exceptional nature of the present season,

Supply required, 13,000 cubic feet.

22. With reference to the proposed supply in canal, it will be seen further on (paragraph 29) that the amount of water required to irrigate the Gogra-Gangetic doab is upwards of 13,000 cubic feet per second. Now, for many reasons, it is needless to take the whole of this amount, even if it was available, from the river at Bunbassa, and the object, therefore, is to fix such a capacity for the canal-channel as to carry down the lowest sufficiency of water to irrigate the tract of country above the point where a new supplementary channel from another river, if necessary, would enable the increased supply thus obtained to provide for the irrigational wants of the country lower down.

Sources of Supply.

Supplementary to Sardah at Bunbassa considered.

23. The supply for the Fyzabad, Benares, Azimghur, Jounpoor, and Ghazeepoor districts would therefore naturally be looked for from the river Gogra, either at or above Byramghát, leaving the remaining districts of Oudh and Rohilkund east of the river Deoba or Gurha to be provided for from the Sardah.

Gogra at Byramghát.

Turning to the drainage map of the doab, sheet No. 2, it will be seen that the reduced level of the water surface of the river Gogra at Byramghát is 614 ; the reduced level of the country near Fyzabad is 629 ; a canal therefore might easily be led in this direction to supply the district of Fyzabad and the portion of Azimghur, Jounpoor, and Ghazepoor, north

of the river Goomtee, south of which it would not be advisable to carry the canal, as the levels show that the Goomtee, in this part of the country, near the Sultanpoor district, where the crossing would have to be, is 60 feet below the water-shed on either side ; and the Sye Nuddee, which runs at the bottom of a like deep channel, would also have to be crossed. A canal, therefore from Byramghát, which would commence irrigating a little below Rudowlie, in the Fyzabad district, must, if required also to irrigate Benares, be carried by heavy embankments at least 40 feet high across the valleys of the Goomtee and Sye, and be taken over the streams by lofty and expensive aqueducts. Admitting that it would be possible to lose level, so as to cross the Goomtee at a moderate height, yet the canal would enter the Sye-Goomtee doab with a cutting at least 30 feet deep, which would not run out under 40 miles, in which length it must be recollected there would not be any irrigation whatever. Objections.

The cost, therefore, of both these schemes, together with the uselessness of leading a channel 40 miles without any irrigation derivable from it, would at once prevent their being adopted.

24. The same objections will on examination be found to apply to the execution of a canal from the Ganges, in addition to the fact that a line from this river would more directly cross all the drainages of the Sye-Ganges doab, and would, therefore interfere most materially with the irrigation that now exists, and which, to a great extent, ought to be maintained from the jhîls and other sources of natural supply in the Roy Bareilly and Pertabgurh districts. Ganges. Objections.

25. The next source of supply for a canal would be the Goomtee, which perhaps might suffice for the wants of the Benares district; but here again we are met with the above objections of deep cutting at a heavy cost, and a useless channel for 40 miles ; besides, in October last year, there was a supply of only 580 cubic feet per second passing down the river at Lucknow, whereas Benares requires upwards of 800 cubic feet. In the beginning of April, I measured a discharge of 1,100 cubic feet at Sultanpoor ; but this was exceptionally high, and probably about 800 cubic feet is the average discharge at that season, which amount, however, could not be abstracted without entirely stopping, for many months in each year, the navigation on the river between Sultanpoor and Jounpoor. Goomtee. Objections.

26. The only possible remaining source of supply would be the Sye Nuddee, which, in November last year, scarcely contained 30 cubic feet per second below Pertabgurh ; so a canal from this stream would be entirely out of the question. Sye.

27. In order, therefore, to irrigate the Benares district in the most economical and efficient manner, it will be seen that we must revert to our original source of supply—the Sardah—for, by thus doing, the whole of the doab, between the Goomtee and the Ganges, will be provided with water on surface ; in no place will there be an expensive deep and useless cutting, as everywhere the canal will have command over the country, and by carrying the canal thus down the water-shed (*vide* sheets Nos. 1 and 2), jhîls which are now used for irrigation will not be interfered with

to the slightest extent, but on the contrary, their usefulness will be increased a hundred-fold, especially in a year like the present, when more than three-fourths are, or were nearly dry, by being able to have their oft-times scanty supplies supplemented from the canal. All the zemindárs and others, with whom I have spoken, are keenly alive to the necessity of having a secure source from whence to fill their tanks, so long as the channel which is to supply them does not interfere in any way with the natural drainages of the country which at present feed the jhíls. At the same time, the zemindárs state that in ordinary seasons they will not take the water, as they can irrigate at less expense from their own jhíls and tanks. It remains, however, to be proved whether their assertion, as to not taking the water, is correct. In the irrigation for rabí crops from jhíls in the Hurdui, Oonao, Roy Bareilly, and Pertabgurh districts, on an average at least two "lifts" are required to raise the water to the surface of the country, and from such data as I could gather, it appears that six men are required for the irrigation of an acre of land per crop. When zemindárs begin to find out that, with water delivered direct from the canal, only one, or at the most two, men are required, and that the labour thus set free will enable them to break up and cultivate more land than they can do at present, I think there is little doubt that they will avail themselves of the cheap and secure supply from the canal, and that the majority of the petty and insignificant jhíls now in use will be abandoned, the small ones only, however, for many of the larger ones, such as the Sandee jhíl in the Hurdui district, and some of the magnificent jhíls in Oonao, Roy Bareilly, and Pertabgurh, as affording auxiliaries to the system of canal irrigation, might well be taken over as imperial works. The second class jhíls irrigating from 200 to 300 acres each, might possibly be left in the hands of their present proprietors, but great improvements could be made to them, if placed, as they undoubtedly would be, if their supply was supplemented from the canal, under the supervision of canal officers.

28. Anyhow, whether zemindárs in the above districts take water or not in ordinary seasons, only a little more than 70 miles of channel will have to be dug to lead water from the tract now requiring irrigation (paragraph 1) to the thirsty lands in the Benares district. It must be remembered, too, that in this length of 70 miles direct irrigation is everywhere available, and that the supplies of jhíls and tanks are rendered independent of the season. Taking the above facts into consideration, I have no hesitation, therefore, in recommending that the supply for the Benares district should be derived from the Sardah, and led down the whole length of the Goomtee-Ganges doab, a distance of 363 miles, or only 14 miles longer than the Ganges Canal from Hurdwar to Cawnpore.

Quantity of water required to irrigate from Mina Kote to Gazeepoor.

29. We come now to the question of the amount of water required to irrigate the country from Mina Kote to Ghazeepoor. Taking, as the standard of calculation, that one cubic foot per second is capable of irrigating 296 acres, and that land is considered to be "highly irrigated," if one-third of the ground within influence of canal irrigation annually takes water, we may consider that one cubic foot per second suffices for the irrigational requirements of 888 acres; or, in other words, that 0·73 cubic feet will give the required irrigation for one square mile of country.

The above calculation is based on data supplied by the statistics of the Eastern Jumna and Ganges Canals; but taking into consideration the fact that in Oudh and Rohilkund less water is required to bring crops to maturity than in the Gangetic doab (for instance, sugar-cane only takes three or four waterings in Rohilkund, whereas 10 or 11 are required in the doab between the Ganges and Jumna,) and that a considerable tract in the former province is covered with jhíls and tanks, I think it may safely be assumed that 0·67 cubic feet per second at the head of irrigation (not the head of canal) will be sufficient for the irrigation of one square mile of country.

15,000 cubic feet discharge required.

Calculating on this assumption, therefore, for the 19,000 square miles of country to be irrigated there would be required 12,730 cubic feet per second at the head of irrigation, and allowing for the amount lost by absorption, &c., between the head of canal and head of irrigation, and for the amount required for navigation, canals discharging an aggregate of 15,000 cubic feet per second would be required for the irrigation and navigation of the doab between the Gogra and the Ganges.

Tateel system advocated.

30. The full amount of water thus required could be obtained by utilizing the supplies both of the Sardah and of the Gogra; but recollecting that each cubic foot of water entering a canal represents a capital of Rs. 4,000, expended in prime cost of construction of works, canals with the above discharge would cost 600 lakhs of rupees. It is matter for serious consideration, therefore, how this amount can safely be reduced without affecting the efficiency of supply. This, however, can fortunately be accomplished by "tateeling" main branches of the canal in the same way as is now done on the Etawah and Cawnpore divisions of the Ganges canal, down each of which the water runs in alternate weeks. Moreover, the conditions of the country to be irrigated in Oudh between Hurdui and Pertabgurh (where the main jhíls and tanks are situated) are much more favourable for this system of irrigation than the arid and parched tracts in Cawnpore and Etawah.

Quantities required under this system.

31. Applying this system, therefore, to the branches which run down the Sye-Goomtee and Sye-Ganges doabs, we find that 3,750 cubic feet per second are required for the irrigation of the latter doab from Kusrawurh (*vide* sheet No. 1) to Benares; adding 350 for navigation, we have a total of 4,100 cubic feet as the supply of the Benares branch at its head at Kusrawurh. From this amount 3,100 cubic feet will be abstracted each alternate week for the supply of the Sye-Goomtee doab, leaving 1,000 cubic feet per second still passing on as a steady and unfluctuating supply for the dry lands in the Allahabad and Benares districts. Adding 10 per cent. as the loss due to evaporation and absorption to the amount supplied at the Kusrawurh branch head, we have as the total supply for the Sye-Goomtee and Sye-Ganges doabs the sum of 4,500 cubic feet per second. On reference to sheet No. 2, it will be seen that 360 cubic feet per second is allotted to rajbuhas for the irrigation of the country between Mina Kote and Kusrawurh, and down to Shahabad. To this must be added 200 cubic feet per second for navigation and for the

supply of the cross line of navigation between Shahjehanpoor and the river Goomtee, which gives a total of 5,050 cubic feet per second at Mina Kote for the supply of the Lucknow and Benares branches of the canal.

32. For the irrigation of the doab between the Kunhout Nuddee and the river Deoha or Gurha, from Mina Kote *vid* Sohas to Shahjehanpoor, 330 cubic feet per second is given. Hence we find that a grand total of 5,390 cubic feet per second is required at Mina Kote for the irrigation of the country between the Deoha and Ganges on the one side, and the Goomtee on the other, the whole of which amount must be taken from the Sardah, if the reasons given in paragraphs 23 to 28, are considered valid.

Supply insufficient for Goomtee Gogra doab.

33. As regards the provision of water for the Goomtee-Gogra doab, it is evident that, if the above amount of 5,390 cubic feet per second is taken from the Sardah at Bunbassa, the remaining supply in the cold season (paragraph 21) will not be sufficient for the requirements of the country from Mina Kote to Fyzabad and Ghazeepoor ; recourse must, therefore, be had to a supplementary channel. On reference to sheet No. 2, it will be seen that I have drawn two possible lines where the levels of the ground show that a new channel could join the canal which runs down the water-shed. The first of these lines takes out from the Sardah near Mujgaen, the idea being that, by placing a dam across the main stream at this point, the supply might be turned down the channel that runs north of Lukhimpoor Kheree, from whence it might be diverted by another dam across the Ool Nuddee, and entering the high land of the doab between Lukhimpoor and Lahurpoor, would join the main canal above the head of the Barabunkee branch. If this scheme was not feasible, then the supplementary channel from the Koreallie, which has a minimum discharge of 13,000 cubic feet (*vide* Appendix A.) was the only remaining method of getting the needful supply ; but the cost of this channel would evidently be very expensive, on account of the numerous drainages which it would have to cross between its head and its entrance into the Bangur. The only map that existed of the tract of country between Lukhimpoor and the Koreallie was one made very many years ago, which now rather misleads than otherwise, as the Sardah and many of the smaller streams have shifted their course very considerably since the original survey was made. The whole of the ground has, therefore, had to be re-surveyed, and in addition levelled over. This work has now been completed by Mr. Heaford, Executive Engineer (although time has not admitted of plotting the surveys as yet on the accompanying sheets,) and proves the entire practicability of leading out the supplementary channel from the Sardah at Mujgaen, where, on the 24th November last year, the discharge of the river (which, it must be recollected, is exceptionally low) was 7,556 cubic feet per second. A minimum supply of 5,000 cubic feet, which is sufficient for the supplementary channel, may, therefore, confidently be reckoned upon at this point when the river is at its lowest, as the abstraction of the water at Bunbassa will probably not materially affect the quantity passing Mujgaen, 70 miles lower down the river.

Proposal for supplementing it.

Supplementary supply from Mujgaen.

33½. From the point where the supplementary channel enters the main canal up to Mina Kote, the quantity of water required for irrigation and navigation is 960 cubic feet per second ; adding 100 cubic feet as loss

by evaporation and absorption, and 150 cubic feet as the supply of the Poorunpoor and Keeruthpoor rajbuhas, we have a total of 1,210 cubic feet per second required at Mina Kote in addition to the 5,390 cubic feet required for the Lucknow and Benares branches, or a grand total at Mina Kote for the supply of the Lucknow, Benares, and Fyzabad main lines of 6,600 cubic feet per second. Adding a loss of nearly 8 per cent., or 514 cubic feet per second, for evaporation and absorption between Nuglah and Mina Kote, the discharge of the required canal at head will be 7,114 cubic feet per second.

34. This is more than the discharge of the river at Bunbassa in January, February, and March (*vide* paragraph 21); but in April the average daily supply is 7,000 cubic feet per second, which steadily increases until the commencement of the rains. In April the water is more particularly required for breaking up and preparing the ground for the kharîf crop; and in September, when there is always an ample supply in the river, the first waterings are taken for the preparation of the land for the rabí. If therefore full supply is maintained in the canal for these two months, the kharîf crop will infallibly be secured, and should the river fall exceptionally low in January, February, and March, yet the full amount of land for the rabí will have been prepared, at least one full watering given to the young crop in November, and sufficient water will still remain in the canal to furnish more than half full amount for the other two waterings. I think, therefore, that there can be little doubt as to determining the full supply of the Sardah Canal at its head at Nuglah at 7,114 cubic feet per second.

Dimensions of canal at Nuglah determined.

35. We have now to consider the amount of water required for the irrigation of the country below the supplementary channel. Calculating on the same data as before, 3,350 cubic feet per second will be required for the land between the Kullianee Nuddee and the Goomtee on one side, and the Gogra on the other, as far down as Ghazeepoor, to which must be added 400 cubic feet per second for navigation, and 800 cubic feet for the supply of the Barabunkee branch, giving a total of 4,550 cubic feet per second. Adding 10 per cent. to this amount for absorption, &c., we have, for the required discharge at head of supplementary channel, a grand total of 5,005 cubic feet per second.

Dimensions below Mujgaen supplemental channel.

36. The total quantity of water, therefore, required for the country between the Ganges and the Gogra from Mina Kote to Gazeepoor is 12,119 cubic feet per second, sub-divided as follows :—

For irrigation	9,570
„ navigation	1,180
„ loss	1,369

37. As regards navigation, it will be observed, on inspection of sheet No. 1, that in addition to the main lines of canal which are intended for navigation as well as irrigation, three cross lines solely for navigation have been provided. The first of these, starting from Shahjehanpoor, locks up from the Gurrah to the Lucknow and Benares Main Line above the Kusrawurh branch head, after which it turns off and locks into the Goomtee,

Navigation.

opposite to the spot where the navigation channel from the Fyzabad line falls into the river. This navigation channel takes out above the Barabunkee branch head, but below the supplementary channel, and passing by Khyrabad, Seetapoor, and Mahowlee is fed, *en route*, from the Seetapoor and Koothar branches. Direct communication then is opened, *vid* the supplementary channel from Mujgaen (near the site of the Oudh forests) to Shahjehanpoor and Rohilkund.

The second navigable line proceeds from Cawnpore, *vid* Oonao, Lucknow, and Barabunkee, to Byramghát on the Gogra; and the third line from Alláhabad, *vid* Pertabgurh and Sultanpoor, to Fyzabad. This scheme for navigation, combined with what at present exists on the rivers, will, I trust, be considered amply sufficient for the wants of the Province. Details regarding traffic, &c., have not yet reached me; the subject, therefore, cannot be further entered into at present.

Approximate cost.

38. Until the levels and surveys of the country between Lucknow and Ghazeepoor are completed, it is of course impossible to furnish a correct statement showing the probable cost of the Sardah Canals. These surveys, however, will be finished within a month, after which the designs and detailed estimates will be drawn up; in the meantime Rs. 4,84,76,000 may be considered as a rough approximation to the probable expenditure that will be incurred. This sum has thus been arrived at :—

Taking the discharge of the Ganges Canal at 6,750 cubic feet, and its cost (including the full number of rajbuhas that will have to be made) at Rs. 2,25,00,000, the cost of each cubic foot at head of canal is Rs. 3,333. In the same manner, if the discharge of the Baree Doab Canal is taken at 3,000 cubic feet, and the cost, including navigation works and rajbuhas, at Rs. 1,40,00,000, the cost per cubic foot at head of canal is Rs. 4,666. Similarly, the cost per cubic foot on the projected Soane Canals, from data furnished by Colonel Dickens's estimate, would be Rs. 4,344, and the cost per cubic foot on the Sutlej Canal, as originally designed by Colonel Crofton, was Rs. 3,261, exclusive of navigation works, or say Rs. 3,500, including lockage, &c.

The mean of these amounts is Rs. 3,961, but, for the purposes of a rough estimate, I have taken the cost of each cubic foot of water at the head of the canal at Rs. 4,000. The cost, therefore, of the Sardah Canals, with an estimated discharge of 12,119 cubic feet per second at head, will be Rs. 4,84,76,000

Revenue.

39. With reference to the possible income that may be derived from the Sardah Canals, if we assume that each cubic foot of water in the year irrigates 250 acres only, instead of the theoretical standard of 296 acres (the Ganges Canal Committee stated 414 acres as the irrigating duty per cubic foot), we have a total of 2,392,500 acres that will annually receive water from the 9,570 cubic feet reserved for irrigation.

The average income derivable per acre irrigated on the Ganges and Eastern Jumna Canals, including water-rate and enhancement of land revenue, is Rs. 4. Allowing for the purposes of this estimate that on the

Sardah Canals only Rs. 3 will be obtained, this will give us Rs. 71,77,500; or including navigation dues, mill-rents, and other miscellaneous profits, say Rs. 73,00,000 as the gross income per annum.

40. Against this is to be set the annual expenditure on maintenance, repairs, &c., at Rs. 150 per cubic foot entering the Canal (on the Ganges Canal Rs. 152, and on the Eastern Jumna Rs. 102 per cubic foot), or Rs. 18,17,850, to which must be added Rs. 1,82,150, as the loss of land revenue per annum on 85,000 acres of land taken up by the canal and its distributaries, or a total expenditure per annum of Rs. 20,00,000, leaving a net annual profit of Rs. 53,00,000, or nearly 11 per cent. on the capital invested.

41. If the project for the construction of the Sardah Canals, as above sketched out, is approved of, it will no doubt be noticed that, by simply making the capacity of the Fyzabad main line from Mina Kote to the head of the Barabunkee branch sufficiently large to hold a discharge of 1,760 cubic feet (instead of 960 cubic feet, which is all that it is absolutely required to hold, *vide* paragraph 33), the Barabunkee branch can be supplied from it. By this means, the whole scheme of the canals will be divided into four distinct systems, which can be carried out successively one after the other, so that the large capital of 485 lakhs required for the whole design need not be sunk in one lump sum before any return is given on the money expended, but in four separate portions, each of which will commence paying interest, as the system of canals for which it is allotted is completed.

For instance, if the above capacity of channel is given to the Fyzabad branch head at Mina Kote, it will be seen on reference to sheet No. 2 that the distributaries from this line will provide irrigation for the whole of the doab between the Goomtee and the Gogra from Mina Kote to a point east of Lucknow and Barabunkee, or the main districts where irrigation is most urgently required.

At the same time that the Fyzabad line is thus being executed, the Shahjehanpoor branch also might be dug.

On the completion of the above system, the Benares Main Line, in its whole length from Mina Kote to Benares, might be undertaken.

When this is finished, the supplementary channel from Mujgaen, together with the extension of the Fyzabad Main Line to Fyzabad and Ghazeepoor, could be commenced, and when completed, the Lucknow and Jounpoor line from Kusrawurh could be made; for the 800 cubic feet per second required for the Barabunkee branch would now be supplied from the supplementary channel, and the corresponding amount temporarily carried down the Fyzabad line from Mina Kote would be sent down its proper course—the Benares line—so as to work the "tateels" on the Lucknow and Benares branches as pointed out in paragraph 30.

Field work executed and in progress.

42. In this report I have had occasion at times to allude to the surveys being as yet incomplete. I trust, therefore, that it may not be forgotten that, although nominally these surveys were commenced last

February (1868) by my two assistants and myself, they were then limited only to the tract of country referred to in paragraph 1. The key to the whole work lay in the upper portion between Mina Kote and Burm Deo, of which ground no reliable maps existed, and beyond a longitudinal line, taken by Colonel Anderson in 1857, there were no levels whatever. In the middle of March, the natives begin leaving the country north of Nuglah on account of the unhealthiness of the climate; three weeks therefore was all the time that could be given last year to the survey in the upper portion, and sheet No. 5 shows some of the work that was then done. From Burm Deo to Fyzabad a line of levels was taken, and also from Mina Kote to Kusrawurh, and down the two branches of the then proposed canal to Lucknow and Cawnpore in addition to cross-sections of the country. This was sufficient to enable an approximate estimate to be made out for a canal to irrigate the country lying to the north-west of a line drawn from Cawnpore to Fyzabad, but subsequently it was determined to extend irrigation to Benares, Azimgurh, and Ghazeepoor. The work done in designing and estimating on the old project had, therefore, entirely to be recast, and a new series of levels between Lucknow and Benares and Azimgurh to be taken. These levels, together with the examination of the country north of Kheree for the determining of the proper position for the supplementary channel, and the survey of the left bank of the Sardah, were commenced in October 1868. Many of these surveys are already finished, as well as a line of levels from Bunbassa to Nanuckmutha, for a canal required for the irrigation of districts west of the river Deoha, and in one month from this date the entire series of levels, cross-sections, and surveys, from Burm Deo to Benares and Azimgurh, will be completed—a result which could not have been accomplished in the time that it has been if I had not received the most cordial assistance from all the officers under my orders.

43. But although the surveys are so near completion, it must be recollected that, for every day employed in field work, at least two days' office work is required for plotting, connecting surveys, designing, and estimating; if, therefore, the usual course of completing the whole of the detailed estimates, submitting them for sanction and awaiting the result, is adopted before a commencement has been made of "lining out" the canals, much valuable time will be lost, which, under the peculiar circumstances on account of climatic and other influences in which the works on the upper portion of the Sardah canals will have to be undertaken, is so entirely to be deprecated, that, as will be seen below, I have had no hesitation in marking out the centre line of the canal well beyond the malarious tract, before applying for sanction for so doing.

For it is only from December to March that work can be undertaken with safety in the dense jungle north of Mina Kote; if therefore the canal is not lined out as far as this point before the end of next month, the greater part of a season's work will be lost. The surveys of the upper portion of the island of Chandnee Chowk, and of the branches of the Sardah, were only completed three days ago. These surveys prove, without doubt, that Nuglah is the only spot for the canal head, but although I have the rough plans here in camp, I have neither time nor the estab-

lishment to finish the whole of the detailed designs, &c., which ought first to be submitted for approval. The Inspector General of Irrigation Works provisionally approved of as much of the scheme as was submitted to him in December last; the surveys that have since been done, support, even more favourably than I could have hoped for, the views then expounded. Taking this into consideration, together with the great advantages that will be gained by having the canal from Nuglah to Mina Kote (between which places the only really difficult positions as regards choice of ground exist) lined out, I have commenced the "lock-spitting" on my own responsibility. Already the line has entered the bangur, and before the end of next month I hope to have it completed to Mina Kote. It is carried in its entire distance, with the exception of about two miles, near Sissayah, through dense jungle; a clear width of 400 feet being cut through the forests, timber from which will be stacked so as to be dry and fit for firewood for kilns next cold season. In addition, arrangements have been completed for sinking wells (of which two have already been commenced) at intervals of two or three miles along the main line down the bangur, so as to have drinking water for the large working parties that will be employed in the excavation of the deep cutting from Mina Kote upwards. These wells will, I hope, prevent the workmen resorting, as they otherwise would have to do, to those hot-beds of disease, the putrid waters of the Mala and Hoodeean swamps; or the river Chooka, which is only a degree better.

Lock spitting, &c.,

Wells dug.

Permanent bench marks of masonry are being built at every 500 feet down the centre line of canal, so that the detailed working estimates can at once be drawn out; and after sanction has been obtained, tenders can be invited for the execution of contracts. If the detailed designs are approved of, contractors will thus be enabled at once to commence work early in December 1869, between Mina Kote and Nuglah, as the line will be marked out for them, wells ready, and dry firewood for the brick-kilns. Whereas, if the canal had not now been lined out, contractors could not have commenced work in this upper portion until February next, when barely a month's work could have been done.

If the scheme for the canals, as here submitted, is disapproved of, an expenditure of about Rs. 4,000 only will have been incurred on the lining out, the greater portion of which amount would be reimbursed by the sale of firewood and timber.

44. The predisposing causes of the unhealthiness of the upper part of the country are, I presume, the stagnant air and water,—the former engendered to a great extent by dense forests close to the foot of the hills, and the latter by large jhíls the formation of which, although caused originally by nature, might not perhaps have given rise to such aggravated swamps as now exist had not the hand of man assisted nature to a most material extent in blocking up and choking the drainage outlets. The detailed levels will show that not the slightest difficulty (except perhaps a pecuniary one) exists in getting rid both of the Mala and Hoodeean swamps.

Wherever a road or cart-track is taken through the forest, if the trees were cleared for a width of 200 or 300 feet, leaving a belt only on either side of the road, perhaps something might be attained in promoting a circulation of air.

45. In conclusion, I would beg to state that this report is only intended to exhibit the main outlines of the scheme that will be submitted. Many details are consequently left out. If, however it should be considered too lengthy for a mere sketch, I can only plead as my excuse that I have been obliged to enter into many reasonings which only a Cautley or a Dyas could authoritatively have omitted.

APPENDIX A.

Suggestions and Recommendations contained in Lieutenant Anderson's Diary.

States that the Kullianee Nuddee, and the jhíls in which it arises, being both dry in the dry season, are useless for irrigation.

2. The Goomtee also at Madho Tandah being dry will not be available for the supply of a canal, though the people seemed anxious to have a canal.

3. There was a stream of water, three feet deep and rapid, in the Chowka Nuddee; but it was 50 feet below the level of the line at Madho Tandah.

4. The Hoodi and Jugbooree Nuddees (affluents of the Sardah) join one another where the road from Bilheri to Burm Deo crosses the latter; and a line of canal could not well be carried higher, that is further west, as it would have the disadvantage of requiring a second masonry work on the Hoodi, and of more difficult ground on the banks. States in addition, that the point where the river breaks into two channels above Bunbassa would be a good site for a canal head if a line higher up is unsuitable, although it would involve some heavy cutting.

5. Gives an opinion at first that a canal head could be opened with greater advantage at Naik-ka-Goth than at Burm Deo; as, in the latter case, seven or eight torrents would have to be crossed, whereas, if opened from Naik-ka-Goth, only one stream (the Jugbooree Nuddee) would prove a serious obstacle.

States that the ground between Burm Deo and Naik-ka-Goth is not favourable for a canal, being sandy and low, and subject to inundation, and that the difficulties of opening a canal from Burm Deo appear very great; but that the only obstacle to opening a canal from Naik-ka-Goth, in addition to the crossing of the Jugbooree (already mentioned) would be heavy cutting for two miles. A further examination, however, induced a change of opinion, as it appeared that the river at Naik-ka-Goth being removed a considerable distance from the bank, a channel opened from it would be liable to be crossed by floods, and to act as a trap for silt and rubbish; also, that it would be liable to have its defences turned by the Sookee Nuddee, which falls into the river just above the proposed site for the head.

By levelling from Burm Deo into the high land near Behara-ka-Goth, and onwards to Naik-ka-Goth, it became evident that Burm Deo was not so unfavourably disposed for a canal head as at first sight appeared. A more careful examination showed that the torrents to be crossed by a canal led from Burm Deo would be none of them any great obstacle, except the Sookee Nuddee, which alone would require a water-way of 100 feet; none of the others requiring a more than 50 feet water-way, and most of these will probably be carried *over* the canal. The advantages seem, therefore, to be on the whole in favour of Burm Deo as a site for a canal head. Limestone is found within four miles.

6. States that a gool from the Dhundi Nuddee would be useful. (Khyreegurh.)

7. Mohana Nuddee, not having its sources in the snows, has not a good supply of water in the dry season. In January 1857 its discharge was 140 cubic feet per second.

8. The Mohana Nuddee, though containing (21st January 1857) 200 cubic feet per second at Chedya, would be exceedingly difficult and expensive to dam, and the project is therefore hardly to be thought of.

9. The discharge of the Koreallee is given at 13,082 cubic feet per second, its width 850 feet, maximum depth 12½, and maximum surface velocity 3·67 feet per second on 28th January 1857.

The character of the ground differs from that in the rest of the terai; the soil clayey and hard, and not suited to the production of wheat or other rabí crops. The wells also are deeper (15 feet to 21 feet deep.)

10. States that a canal from the Koreallee is impracticable on account of the hills running too parallel to its course to a long distance to allow of as favourable a head as from the Sardah above Burm Deo. There are, besides, innumerable small obstacles in the shape of hill torrents which, in the aggregate, form a serious obstruction. Besides this, the great height of the bangur land, and the almost impracticable jungle through which the line would have to pass.

11. States that the Girwee (an affluent of the Koореallee at about six miles from the Kuchli), which contained a good stream (on 30th January 1857) produced by percolation, would be a very difficult stream to deal with were a canal to be carried across it.

12. States that the ground near the Chota Surjoo is of good quality, of a stiff clayey texture. There is a cut from the Chota Surjoo, which conveys water, which is used for maturing the rice crops, and before ploughing, but *not* for the rabí crops; also states that the Chota Surjoo appears capable of irrigating more than it is now used for, and that it would be, doubtless, a great advantage to substitute a permanent, in place of the present temporary, dam. At the base of the hills there was a good site for a dam on the Chota Surjoo, the discharge of the river at its maximum about 400 cubic feet per second, enough to supply one canal to supersede the present gool running to Pudnaha.

13. States that a canal from the Chota Surjoo would be very beneficial, that many villages have disappeared, and jungle has encroached for want of water.

14. No chance of a canal from the Raptee, as even were the ground suitable, no site for a canal head is to be found in the Oudh territory; only in Nipál. Discharge of Raptee 935 cubic feet per second (on 27th February 1868).

15. States afterwards (28th February) that the ground near the Raptee would have been very favourable for canal had it been possible to interfere with the Raptee beyond the frontier.

16. States that it would be most advisable to adopt some means to secure the water of nullah beyond Musha (name not given), and as damming it is impracticable, tanks are the only other method, but it is doubtful whether they would not be too expensive (ground near the point where the nullah which passes Lallpoor leaves the jungle suitable for tanks.)

17. The Koanee discharges 20 to 30 cubic feet per second, but the extent of cutting renders it doubtful whether a canal could be formed.

Abstracted from Lieutenant Anderson's diary by the late Lieutenant H. C. Smith, Royal Engineers.

J. G. FORBES, *Captain. R. E.,*

Superintendent, Irrigation Works, Oudh.

APPENDIX B.

Preliminary Report on Survey Operations for Irrigation Works in Oudh, during 1867-68, by Captain J. G. Forbes, R. E., Superintendent, Irrigation Works, Oudh.

With the view of preparing a project for a canal for the irrigation of Oudh, and a portion of the Bareilly and Shahjehanpoor districts, the following establishment was appointed to the province :—

CAPTAIN FORBES, R. E., *Superintendent.*
MR. HENSLOWE, *Assistant Engineer.*
„ FROUDE, „ „
DRUMMER GROVES, *Overseer.*

2. Commencing so late as the survey did this year, field-work not being begun until February, I was obliged to confine my attention solely to gathering sufficient data to enable Government to judge of the feasibility of the project, and to collecting such information as would enable me to send in an approximate estimate of the probable cost of canals, leaving the collection of details and *minutiæ* for subsequent works in the ensuing cold season.

3. The surveys, &c., were accordingly apportioned out as follows :—

For myself I reserved the survey and levelling of the upper portion of the river Sardah, and the tract of country in the Terai where the main engineering difficulties would be; the choice of site for canal heads, the measurement of the rivers, and the examination of the hills for stone, lime, and other materials; besides a general reconnoissance of the whole province, (and part of the North-Western Provinces) from Burm Deo to Fyzabad.

To Mr. Henslowe was entrusted the levelling of two cross-sections, and the longitudinal lines for two possible branches of a canal—

1*st*, down the doab, between the rivers Ganges and Sye, joining the former stream at Cawnpoor;

2*nd*, down the doab, between the rivers Sye and Goomtee, falling into the latter at Lucknow.

Mr. Froude levelled down the main lines from a point about 30 miles below Burm Deo to Fyzabad, where the proposed canal would join the Gogra.

Overseer Groves was employed in levelling cross-sections in the Kheree, Seetapoor, and Shahjehanpoor districts.

4. The dates on which field-work was commenced by each officer were as follows :—

Captain Forbes,	February	13th,	1868.
Mr. Henslowe,	,,	8th,	,,
Mr. Froude,	,,	27th,	,,

By the latter end of April the whole of the work specified in the preceding paragraph was completed.

Six hundred and thirty-nine miles of levelling, besides a rough prismatic survey of upwards of 1,200 square miles of country was finished, the chief portion being levelled by Messrs. Henslowe and Froude, who, respectively, did 267 and 231 miles.

The reduced levels of 210 bench-marks were fixed; connections were made with the levels of the Rohilkund contour survey, the Ganges canal, the great trigonometrical survey, and with a series taken by Lieutenant (now Lieutenant-Colonel) Anderson, of the Madras Engineers, in 1856-57.

The spring surface level of water in all the wells met with *en route* was measured; and careful notes were made regarding irrigational requirements of the districts passed, the proximity of materials and labour, besides a large amount of miscellaneous information, which will come of use when drawing up the project.

5. The main facts elicited by the surveys are,—

1*st*, the entire practicability of constructing a first class canal for irrigation and navigation from the river Sardah through the tract referred to in paragraph 1;

2*nd*, that at a short distance below the debouchure of the river from the hills there are two sites, either of which are well adapted for the construction of the head works of a canal;

3*rd*, that the supply in the Sardah is sufficient for the irrigation, &c., of the country as far as Fyzabad; and

4*th*, that, if required, the canal can most probably be extended to the Azimgurh and Jounpoor districts by having a supplementary head near the junction of the Sardah and Koreallee.

6. The detailed report and estimate are now in course of preparation, and will be submitted shortly.

J. G. FORBES, *Capt., R. E.*,
Superintendent, Irrigation Works.

LUCKNOW:
The 24th August, 1868.

APPENDIX C.

QUESTION 1.—Whether irrigation from streams, jhíls, or other natural sources is now practised? If, so, to what extent? Actual areas being stated, if possible, otherwise an approximation to be given.

Shajehanpoor.—About 101,726 acres are thus irrigated, or about 20 per cent. of total area cultivated.

Kheree (Lukhimpoor).—Estimates vary from 12 to 25 per cent of total area in district as irrigated at present from bunds placed across small streams.

Seetapoor.—Out of 915,328 acres under cultivation, only 154,610 rather under 17 per cent.) are irrigated; of these, 65,213 acres are watered from wells, and 89,397 from tanks, &c.

Hurdui.—Irrigation is practised from all the sources mentioned. The cultivated land amounts to 861,495 acres, of which 263,990 (or 31 per cent.) is irrigated.

Barabunkee (Nawabgunj).—Irrigation is but little practised, and is supplied from tanks to 96,262 acres only.

Lucknow.—Irrigation is practised, but no information is given regarding areas, excepting in the case of one tahsíl, which contains 59,547 acres of cultivated ground, of which about one-half is supplied with water.

Oonao.—The irrigated land amounts to 117,000 acres.

Roy Bareilly.—Irrigation is extensively practised, chiefly from jhíls, wells and tanks. The total of cultivated land is 428,366 acres, of which 308,624 acres (about 72 per cent) are watered,—164,617 acres, from *wells* and 144,007 from other sources,

Sultanpoor.—Irrigation is practised in every village from natural jhíls and artificial tanks. The cultivated land amounts to 503,856 acres, of which 393,180 are irrigated. This is equal to 77 per cent, but probably includes the land watered from wells.

Fyzabad.—393,091 acres are irrigated in this district, but the total area of land under cultivation is not mentioned.

Pertabgurh.—348,503 acres are irrigated.

Benares.—Irrigation is practised, wherever possible, from small streams, jhíls, &c., which however generally dry up in the hot season. Only 77,337 acres are irrigated.

Azimgurh.—No answer.

Jounpoor.—No answer.

Ghazeepoor.—Ditto.

QUESTION 2.—If irrigation is anywhere practised, do the landholders pay any rate to Government for the use of the water? If not, have they any prescriptive right to use it?

No rate is in any case paid throughout Oudh. In some districts (as Oonao) the prescriptive right of landowners is definitely recorded; in some the records are incomplete, in others again no records are kept. No answers, however, have been returned from Seetapoor, Fyzabad and Lucknow.

Where the irrigation is from tanks, each village has its particular channels of supply, and in dry seasons violent disputes arise between both villages and individuals. At the revised settlement, their respective rights are defined and recorded.—R. H. D.

In Shahjehanpoor the landholders do not pay anything to Government for the use of the water from rivers, jhíls, &c.. as also in Benares, where landowners have a prescriptive right to use the water.

That is to say, they pay no separate water-rate, but the Settlement Officers put a higher rate on irrigated than unirrigated rate. Benares being under permanent settlement, doubtless enjoys free any irrigation introduced since it was concluded.—R. H. D.

QUESTION 3.—What is the average depth of water below the surface of the ground? State also the maximum and minimum depths, specifying the names of places where the water is found at greatest and least depth?

Shahjehanpoor,	Average depth	12	feet.
	Greatest „	21	„ on the higher land, and
	Least „	2	„ in the khadir of river
Kheree,	Average depth	5 to 7	„ in khadir.
	„ „	30 to 45	„ in bangur.
	Maximum	45	„ in Lukhimpoor.
	Minimum	4	„ in the khadir close to Lukhimpoor.
Seetapoor,	Average depth	21	feet.
	Maximum	50	„ in Unchietta.
	Minimum	10	„ in Sudurpoor.

Hurdui,	Average depth	28 feet.
	Maximum	40 „ in Mullaon.
	Minimum	14 „ in Palee.
Barabunkee,	Average depth	20 feet.
	Maximum	40 „ and
	Minimum	10 „ in the khadir of the Gogra.
Lucknow,	Average depth	25 feet.
	Maximum	80 „
	Minimum	12 „
Oonao,	Average depth	38 feet.
	Maximum	112 „ in Oonao.
	Minimum	12 „ in Suffeepoor.
Roy Bareilly,	Average depth	30 feet.
	Maximum	78 „ in Beegapoor.
	Minimum	8 „ in Parakhow.
Sultanpoor,	Average depth	20 feet.
	Maximum	45 „
	Minimum	12 „
Fyzabad	...Average depth	26 feet.
	Maximum	42 „ in Soorhoorpoor.
	Minimum	22 „ in Issolee.
Pertabgurh,	...Average depth	23 feet.
	Maximum	45 „ in Mudhpoor.
	Minimum	13 „ in Salone.
Benares,	...Average depth	57 feet.
	Maximum	112 „ in Nanwuh (Pergana Dehutamaunt.)
	Minimum	15 feet in Nypoora (Pergana Dehutamaunt).

QUESTION 4.—Do facilities exist for making "kacha wells?" If so, are there many in use for irrigation purposes, and what is the average cost of making the wells?

"Kacha" wells are very extensively used all over Oudh. The several returns agree so well, it is unnecessary to give details of each answer. It appears that "kacha" wells in loose soils cost from Rs. 2 to Rs. 3, but are serviceable for only one season. Those in stiffer soils (which may last four or five years) cost from Rs. 6 to Rs. 10, according to depth. And such as require lining with cylinders, &c., set in mud, involve an outlay of from Rs. 30 to Rs. 40.

In the stiff clay soils these wells are said to last as long as 50 years. R. H. D.

In Shahjehanpoor there are a great number of "kacha" wells in use, the average cost of making them being Rs. 3. In Benares also there are very many wells, but more are required; average cost varies from Rs. 3 to Rs. 5.

In Ghazeepoor there are a great many wells all over the district, and the average cost of making them is Rs. 15.

QUESTION 5.—Do facilities exist for making minor irrigation works from tanks, jhíls and nullahs, or other sources? If so, state the portion or portions of the district which would probably be benefited, aud point out which work it would be requisite to undertake first ?

Seetapoor and Lucknow have not noticed the question. Oonao states repairs are required to existing bunds, and Roy Bareilly finds its jhíls silting up and requiring to be deepened; protection is also required against inundations of the river Sye. Shahjehanpoor recommends construction of large canal, either from the Sardah or the Ramgunga in preference to minor works.

In the Seetapoor district and on a straight line drawn down through the Fyzabad district, there are a few facilities for irrigation apart from a canal from the Sardah or Koreallee. On the right bank of the Goomtee, it is otherwise; but the consideration, in strong support of introducing a perennial supply of water, is the density of the population averaging, perhaps, as much as 500 to the square mile. A famine perhaps does not occur once in 50 years, but when it does come the effect is appalling.—R. H. D.

In Benares no minor irrigation works are required, as "the people do very well without them in the rainy season, and in the hot months the jhíls and nullahs generally dry up."

QUESTION 6.—In the event of irrigation works being carried out, state whether any special arrangement should be made with reference to charging for the water supplied, contingent on any peculiarity of the tenure of land or otherwise; and mention what would be the probable fair money value of water to the chief crops likely to require it ?

In none of the districts in Oudh does there appear to be land under any particular tenure requiring special arrangements with reference to charging for water supplied. The money value for water to crops is estimated as follows :

The tenures are practically much the same as in the North-Western Provinces.

"It has been shown that in the populous parts of the province, a large proportion of the cultivated area is irrigated already."

Much of this will be discontinued on the canal water appearing. It is a question how the total increase of revenue shall be assessed. Personally, I recommend the reduction of the present land revenue, and a strict assessment of the canal tax, wherever the canal irrigation supersedes the other, but the question is of great importance and requires much examination and discussion.—R. H. D.

Kheree.—Six annas to eight annas per acre, "but likely to increase when the advantages of regular water-supply are better known."

Hurdui.—It is said landowners would not take water if it cost more than Rs. 1-8 to Rs. 2-4 per acre; but the Deputy Commissioner is satisfied from personal observation of the present working and cost (the details of which he describes) that Rs. 3 per acre would be about the fair average value.

Pertabgurh.—Mentions 8 annas to 1 Rupee per acre per *watering* for cereals, for tobacco Rs. 2 per acre per crop, for sugar-cane Rs. 3, and for poppy Rs. 4.

Fyzabad.— States Rs. 1-4 per acre for ordinary crops, and Rs. 2-8 for sugar-cane, poppy and tobacco.

Shahjehanpoor.—Estimates an average rate of 6 annas per acre for all crops.

These rates appear to me much too low.—R. H. D.

Benares and *Ghazeepoor* do not notice the question.

QUESTION 7.—Is the settlement of land revenue permanently fixed or not?

The only land permanently settled in Oudh is an estate of about 150,000 acres, which was conferred on the Rája of Kupoorthulla. In Oonao, Barabunkee, Pertabgurh, and Fyzabad, it is fixed for 30 years. In Hurdui it is now in course of settlement. The other districts in the North-Western Provinces do not notice the question, but it is believed that in some parts of Benares and Ghazeepoor a permanent settlement prevails.

This is the case at present. But the Rája of Bulrampoor and three other ta'lukdárs are entitled under the orders of Government to a permanent assessment, and some of their estates are of great extent—R. H. D.

QUESTION 8.—In what months are the first waterings for breaking up and preparing the land for the kharíf and and rabí crops required?

Very few of the districts answer this question, but those that do, agree in stating that water is required for preparing the land for the kharíf from April to the beginning of the rains, and for the rabí in September and October.

Also at the end of February, or beginning of March, especially when there has been no cold weather rain. R. H. D.

The proportion of kharíf to rabí is about 6 to 10 in the lower parts of Oudh near Fyzabad.

QUESTION 9.—What are the more important crops of the district? Give approximate areas of cultivation?

Only one or two districts give approximate areas of cultivation. The remainder simply particularise the crops, *viz.*, sugar-cane, tobacco, rice, wheat, barley, indigo, poppy and cotton.

These particulars are not ascertainable even from the settlement papers. R. H. D.

QUESTION 10.—What is the weight of the ordinary produce of the chief crops per acre, irrigated and unirrigated?

Estimates founded on data more or less reliable are given by all districts.

The different weights of ordinary produce per acre range between wide limits; but the proportions of yield from irrigated and unirrigated ground varies but little throughout, except in the Kheree district, where the wetted ground is said to yield four times as much as the dry. The other districts shew an increase by irrigation of between 50 and 100 per cent, the average percentage of all districts being about 70.

QUESTION. 11.—Is there at present any important export of agricultural produce? If so, to what places, and what are the chief staples?

Shahjehanpoor.—Wheat, gram, and barley are exported to Futtehgurh, Cawnpoor, and Mirzapoor, also to Bareilly.

Kheree.—Produce is sent to Rohilkund, Lucknow, and Cawnpoor.

Seetapoor.—Produce sent to Cawnpoor Oonao, and Shahjehanpoor.

Hurdui.—Grains and sugar to Cawnpoor and Lucknow.

Barabunkee.—Produce sent to Cawnpoor and Lucknow.

Lucknow.—Grains, sugar, and tobacco to Cawnpoor; opium to Fyzabad and Ghazeepoor.

Oonao.—Produce chiefly sent to Cawnpoor.

Roy Bareilly.—Grain of all kinds to Cawnpoor and Futtehpoor.

Sultanpoor.—Grains and oil-seeds to Jounpoor, sugar to the "West."

Fyzabad.—Large exportations of produce down the Gogra and Goomtee.

Pertabgurh.—Grain of all kinds, as well as sugar, tobacco, and opium are exported to Allahabad, Mirzapoor, Cawnpoor, and Futtehpoor.

Benares.—Sugar to Calcutta, Mirzapoor, and Calpee; indigo to Calcutta, and opium to Ghazeepoor.

QUESTION 12.—Is there any "reh" or oosur land in the district? If so, specify where and state actual or apporximate areas?

Shahjehanpoor.—About 8,000 acres in the southern portion of district.

Kheree.—230 acres interspersed.

Hurdui.—78,038 acres.

Barabunkee.—No "reh," very little "oosur," and that scattered.

Oonao. { 16,990 acres reh / 109,026 „ oosur } scattered over district.

Roy Bareilly.—62,425 acres oosur; locality not mentioned.

Sultanpoor.—Large tracts all over the district; area not stated.

Fyzabad.—160,501 acres.

Seetapoor and Lucknow do not answer the question.

Benares.—2,200 acres oosur carefully specified.

RAIN-FALL.

The average amounts of rain-falls furnished by the few districts which have sent in returns are not sufficient to base any approximate average on.

Abstracted from detailed replies of district officers.

J. G. FORBES, *Captain, R. E.*
Superintendent, Irrigation Works, Oudh,

APPENDIX D.

Statement of Annual Imports and Exports of (British) Burm Deo.

IMPORTS.

From the Hills and Thibet..	*Value.* Rs.
Borax, ...	1,00,000
Turmeric, ...	50,000
200 maunds ghee, at Rs. 20 per maund, ...	4,000
500 „ khutta for pan and dyes, at Rs. 16 per maund,	8,000
Total, ...	1,62,000

From Nipál.

Maunds.					*Rs.*
1,500	cardamums, at Rs.	40	per maund,		60,000
500	ghee,	20	„	...	10,000
1,500	ginger	15	„	...	2,250
200	wax	40		... ...	8,000
5000	balchar (for medicines and perfumes, at Rs. 12)				6,000
400	khutta at Rs.	16	„	... ...	6,400
			Total,	...	92,650
	Grand total value of imports,			...	2,54,650

EXPORT.

To the Hills and Thibet.

Maunds.		*Rs.*
1,500	salt, at Rs. 6-8	9,750
2,000	sugar „ 4-0	8,000
	Cloth, ...	60,000
	Miscellaneous, tobacco, spices, &c., ...	2,000
	Total, ...	79,750

To Nipál.

Maunds.		*Rs.*
6,000	salt, at Rs. 6-8 per maund, ...	39,000
800	„ „ 4-0 „	3,200
	Cloth, ...	50,000
	Miscellaneous, tobacco, brass and copper vessels, spices, &c.,	5,000
	Total, ...	97,200
	Grand total exports, ...	1,76,950
	Grand total imports and exports, ...	4,31,600

Export dues in (Nipálese) Burm Deo.

Cardamums, at Rs.	5	per	100	(British)	seers.
Ghee,	„ 4-12	„	100	„	„
Ginger,	„ 3-8	„	100	„	„
Wax,	„ 10	„	100	„	„
Balchar	„ 4	„	100	„	„
Khutta	„ 4	„	100	„	„

Duty in (British) Burm Deo.

Khutta, at Rs. 15 per 100 seers.

All other articles free.

This statement is compiled from the best information I could get from the traders and others at Burm Deo.

J. G. FORBES, *Capt., R. E.,*
Superintendent, Irrigation Works, Oudh.

Supplementary Note on Sardah Canal Project, by Captain J. G. Forbes, R. E., Officiating Superintending Engineer, Sardah Canal.

1. Appendix J, and para. 39 of the Sardah Canal Report showed that in the Roy Bareilly, Pertabgurh, and Sultanpoor districts, the present irrigated tract is already 73, 74 and 78 per cent. of the cultivated area; but in order to provide water for the Benares district, it was stated, in paras. 15 to 37, that it was more economical to lead the water from the River Sardah down the whole length of the Doáb, through these already well watered districts, than to take out a supplementary channel from either the Ganges or Gográ. Since the project was submitted, five other schemes have been worked out, in order to see if it was not really financially practicable to take a supply from either of these two rivers; but the results show that the conclusions arrived at in the report were correct, *viz.*, that the head of canal should be on the River Sardah at Nugláh, and that any supplementary channel should be from the same river.

2. In para. 115 of the report, it was pointed out, that in the event of its being finally determined that water was *not* required for the whole of Oudh, the estimates and details of the proposed canal were so complete that, by a slight alteration, they could be re-cast, so as to show the cost of any alternative proposition that might be brought forward.

3. It has now been determined that irrigation is not absolutely necessary for the three districts mentioned in para. 11, and that the supply for the Benares district may as yet be left in abeyance. A modification of the original project is therefore rendered necessary, especially as it is now considered that navigation is not required for all the branches of the canal, as navigable rivers already exist, running parallel to, and at a distance of only a few miles from the proposed lines of canal, (*vide* Appendix 1).

4. The present proposed canal, as will be seen on reference to accompanying map, takes out from the original head at Nugláh, and is carried down on the original alignments; the Benares branch, however, for the present stopping midway between Hurdui and Cawnpore, and the Jounpore branch falling into the Gúmtí at Lucknow, thus providing for the irrigation of all the Cis-Gográ districts in Oudh, (with the exception of Roy Bareilly, Pertabgurh and Sultanpoor, and also for those portions of Shahjehanpore, and Bareilly, situated on the east of the River Gurhá.

5. Navigation is provided for on the Benares branch, as far as Sissorí, from which place navigable channels will lock into the Rivers Gurhá and Gúmtí.

The Fyzabad branch will also be navigable as far as Unchá Kherá, and from thence to Lucknow.

6. The amount of water required at Nugláh is 5,014 cubic feet per second; which has been distributed as follows:—

Fyzabad and East Lucknow branch,	... ...	2,370
Hurdui and West Lucknow branch,	... ...	2,082
Shahjehanpore, ...	... ...	351
	Total, ...	4,803

The balance of 211 cubic feet, being available for navigation. But in calculating the returns, (paras. 14, &c.,) credit has only been taken for 4,500 cubic feet, as utilized in irrigation, the other 303 cubic feet being supposed to be expended in evaporation and absorption.

In addition to this, provision has been made for the admission of 800 cubic feet per second more water at Nugláh, without unduly accelerating the velocity of the stream in the canal; so that if eventually it should be found necessary to provide for the irrigation of the Azimgurh and Jounpore districts, the only extra expense will be the cost of constructing a few irrigation channels.

7. The estimates herewith accompanying show that the probable expenditure on the canal will be Rs. 3,01,78,852, and further on (para. 14), it will be seen that after taking into account the loss of interest, (Rs. 81,40,756) on the capital outlay, while the works are being executed, the net returns at the end of 17 years, when irrigation will come into operation, will be upwards of 8 per cent. on the accumulated capital, Rs. 3,83,19,608,* or 11 per cent. on the original outlay of Rs. 3,01,78,852.

8. Should it be deemed advisable hereafter to extend irrigation as far as Benares, it can be accomplished by leading out a supplementary channel from the River Sardah at Kumáriághát, (21 miles above Delahá), where the levels show the practicability of taking a canal (as shown by the red line on map) to Sissorí, the head of the Gúmtí Ganges Doáb.

9. As an impression apparently prevails that water is everywhere met with in Oudh, within a few feet of the surface, I would draw attention to Appendix C of General Report, dated 10th February 1869, where it will be seen that in the "Bangur," or high land, where *alone* is the canal taken, the spring level of water is in:—

Kheree, ...	30 to 45	feet	below the ground.
Seetapoor, ...	21 to 50	„	„
Hurdui, ...	28 to 40	„	„
Barabunkee, ...	20 to 40	„	„
Lucknow,...	25 to 80	„	„
Oonao, ...	38 to 112	„	„
Roy Bareilly, ...	30 to 78	„	„
Sultanpoor, ...	20 to 45	„	„
Fyzabad, ...	26 to 42	„	„
Pertabgurh, ...	23 to 45	„	„

* Original outlay ... ... Rs. 3,01,78,852
Loss of interest ... ... „ 81,40,756
„ 3,83,19,608

Income and Expenditure.

10. In the original report, the probable returns of the Sardáh Canal were shown as 8½ per cent. on the capital. The loss of interest on the capital outlay, while the works were under execution had not been overlooked; but, as in para. 13 of Government of India, Public Works, letter, No. 3631, dated 9th October 1869, it was stated that, after taking into account the above loss of interest, a return of 7 per cent. on the *original* capital was sufficient to protect Government from loss; and as the percentage on the canal worked out to 8½ or 1½ per cent., more than the limit fixed, I did not think it necessary to enter into details regarding the accumulated interest, &c.

In this present scheme agreeably to Inspector General of Irrigation Works orders, I have below shown the probable returns according to his mode of calculation, after including the accumulated compound interest during the execution of the works.

11. Of the total amount of Rs. 3,01,78,852 required to complete the canal, it is proposed to expend, at first only Rs. 174,47,424 in the construction of the Shahjehanpore, Fyzabad, (to Unchá Kherá), and Lucknow branches, (*vide* para. 111 of report).

This first part of the scheme will, it is supposed, be completed in seven years; at the end of which period the original amount of Rs. 1,74,47,424 with accumulated interest at four per cent. will have increased to Rs. 2,04,77,747. But as irrigation will not have developed for five years more, a further sum of Rs. 20,47,774 or 10 per cent. on the above capital, will have to be added, so that at the end of 12 years, the probable accumulated capital will be Rs. 2,25,25,521.

12. The number of acres that will be irrigated is 508,000, (para. 111 of report), and the water-rate being taken at only Rs. 2-8 per acre; the gross returns will be Rs. 12,70,000, to which must be added Rs. 1,10,434, (the same proportion as on the Ganges Canal) for miscellaneous dues; or a total of Rs. 13,80,434. From this has to be deducted the probable cost of maintenance at eight annas per acre, (or Rs. 125 per cubic foot of water in canal) = Rs. 2,54,000 and the net returns will be Rs. 11,26,434, or exactly five per cent. on the *accumulated* capital of 225¼ lakhs.

This, it must be recollected, is exclusive of enhancement of land revenue, which if calculated at only 12 annas per acre,* on the area irrigated, will give Rs. 3,81,000; or a total net income of Rs. 15,07,434; or 6·69 per cent. on the capital.

Even putting the maintenance charges as high as 10 annas per acre, or Rs. 156 per cubic foot of water in canal, (para. 108 of report), the net returns on water rate and miscellanous dues, alone, will be Rs. 10,62,934, or 4·71 per cent., and if enhanced land revenue is included, Rs. 14,43,934, or 6·41 per cent.

---

* In the North-Western Provinces it is 14 annas per acre; and in the Punjab 13 annas 9 pie.

13. When this first part of the scheme is completed, the remaining portion can be carried out. This will cost Rs. 1,27,44,400, and as the heavy works at head of canal will already have been completed, this latter portion will probably be finished in five years.

Going through the same calculation as before, we find (Appendix 2), that the accumulated capital will be Rs. 1,57,94,087, and the gross returns (excluding land revenue), Rs. 16,76,630, which, at eight annas per acre maintenance, will give an income of Rs. 13,68,130, or 8·66 per cent. on capital; taking maintenance at 10 annas per acre, the net income will be Rs. 12,91,005, or 8·17 per cent.

Including land revenue, the net income at eight annas per acre maintenance, would be Rs. 18,30,880, or 11·59 per cent.; and if the maintenance charges are taken at 10 annas per acre, the net returns would be Rs. 17,53,755, or 11·10 per cent. on the accumulated capital.

14. At the end of 17 years, both schemes will come into operation. The accumulated capital will be Rs. 3,83,19,608, and the gross returns of water rate and miscellaneous dues, Rs. 30,57,065. Taking maintenance at eight annas, the net income will be Rs. 24,94,565, or 6·50 per cent. on the capital, at 10 annas per acre maintenance, the net returns would be Rs. 23,53,940, or 6·14 per cent.

Including land revenue, the net returns would be Rs. 33,38,315 and Rs. 31,97,690; or 8·71 and 8·34 per cent. on the accumulated capital, or 11·06 and 10·60 on original capital, according as the maintenance charges are taken at eight annas, or ten annas per acre.

SIMLA,
25th September 1871.

J. G. FORBES, CAPT., R. E.,
Officiating Superintending Engineer,
Sardah Canal.

Appendix 1 to Supplementary Note on Sardah Canal Project.

Extract from letter dated 19th February 1868, to Inspector General, Irrigation Works.

In the part of the country which will come under the influence of the Canal, there are already two main navigable lines, the Ganges and Gogra, open all the year round; and three minor streams, *viz.* the Gurhá, which is navigable from Shahjehanpore to the Ganges; the Gúmtí, navigable for rafts from Mohumdee, and for boats from Lucknow; and the Sye, navigable, I believe, from Roy Bareilly. These three latter streams, not having their sources in the snows, are at their lowest in May and June, and navigation if not entirely stopped, is considerably impeded in April, which is the month in which we will be able to spare water from the Canal (vide paragraph 21 of Report of 10th February 1869, and paragraph 47 of Report of 1st September 1870.) I therefore consider that their supplies should be supplemented from the Canal, that the present navigation on them should be improved by dams, locks and "cut-offs"; that, in the upper parts of the Doábs, navigable channels, fed from the main canal, should be made from one large town to another, locking in and out of the irrigation line where necessary; and that these navigable lines should tail into the rivers, as follows, *viz.* :—

1. Into the Gurhá at Shahjehanpore.
2. Into the Sye at Roy Bareilly.
3. Into the Ganges at Cawnpore.
4. Into the Gúmtí at Lucknow.
5. Into the Gogra at Byramghát with extension down main irrigating line to Fyzabad.

All these lines to be connected with one another by cross lines, running from town to town.

J. G. FORBES, *Capt., R. E.,*

Officiating Superintending Engineer, Sardah Canal.

Appendix 2.

INCOME AND EXPENDITURE.

1st Portion of Scheme.

Expenditure.

	Cost Rupees	Water. Cubic feet per second.
Supply Channel, ...	4,94,844	
Main Canal, ...	55,39,632	
Shahjehanpore Branch, ...	9,76,620	351
Fyzabad Branch to Unchá Kherá, ...	52,32,080	1,065
Lucknow Branch, ...	18,96,071	616
Tramway, ...	18,00,000	
Tools and Plant, ...	10,00,000	
Total, ...	1,69,39,247	2,032
Establishment for accounts at 3 per cent.	5,08,177	
Total cost, ...	1,74,47,424	
Annual expenditure $\frac{1}{7}$, ...	24,92,489	
Works to be completed in 7 years, annual expenditure, say, ...		24,93,000
24,93,000, plus 4 per cent for 7 years compound interest,		32,80,538
Do. do. 6 do. do.,		31,54,392
Do. do. 5 do. do.,		30,32,983
Do. do. 4 do. do.,		29,16,311
Do. do. 3 do. do.,		28,04,375
Do. do. 2 do. do.,		26,96,428
Do. do. 1 do. do.,		25,92,720
Total at end of 7 years, ...		2,04,77,747
Add for 5 years more at 2 per cent.		20,47,774
Grand Total,...		2,25,25,521

Income.

Cubic feet of water per second, ...	2,032
Area irrigated at 250 acres per cubic feet, ...	5,08,000

A.

Income derived from water rate at Rs. 2·5 per acre 5,08,000 × 2·5, ...	12,70,000
Miscellaneous dues 92 : 8 : : 12,70,000,...	1,10,434
Gross revenue, ...	13,80,434
Deduct maintenance at 8 annas per acre 5,08,000 × ½,	2,54,000
Leaving a net return of, ...	11,26,434

or 5 per cent. on capital of 2,25,25,521.

Adding for enhancement of land revenue at 12 annas per acre irrigated or 5,08,000 × 12 annas, ...	3,81,000
Gives total net income of, ...	15,07,434

or 6·69 per cent on capital.

B.

Income derived from water rate at Rs. 2·5 per acre 5,08,000 × 2·5, ...	12,70,000
Miscellaneous dues 92 : 8 : : 12,70,000, ...	1,10,434
Total, ...	13,80,434
Deduct for maintenance at 10 annas per acre,... ...	3,17,500
Leaving a net return of, ...	10,62,934

or 4·71 per cent. on capital.

Adding for enhancement of land revenue at 12 annas per acre irrigated 5,08,000 × 12 annas, ...	3,81,000
Gives total net income, ...	14,43,934

or a return of 6·41 per cent. on capital of 2,25,25,521.

2ND PORTION OF SCHEME.

Expenditure.

	Cost Rupees	Water. Cubic feet per sec.
Total cost of Canals, ...	3,01,78,852	4,500
Portion of do. completed in 1st 7 years,	1,74,47,424	2,032
Remainder to be completed in 5 years,	1,27,31,428	2,468

or per annum, say 25,49,000.

25,49,000 plus 4 per cent. for 5 years' compound interest,					31,01,113
Do.	do.	4	do.	do.,	29,81,820
Do.	do.	3	do.	do.,	28,67,370
Do.	do.	2	do.	do.,	27,56,998
Do.	do.	1	do.	do.,	26,50,960
				Total,	1,43,58,261
Add for 5 years more at 2 per cent.					14,35,826
				Total Capital, ...	1,57,94,087

Income.

Cubic feet of water per second,...	2,468
Areas irrigated at 250 acres per cubic foot, ...	6,17,000

A.

Income from water rate on 6,17,000 acres at 2·5, ...	15,42,500
Miscellaneous dues 92 : 8 : : 15,42,500, ...	1,34,130
Gross revenue, ...	16,76,630
Deduct maintenance at 8 annas per acre 6,17,000 at 8 annas, ...	3,08,500
Leaving a net return of, ...	13,68,130

or 8·66 per cent. on capital.

Adding for enhancement of land revenue at 12 annas per acre or 6,17,000 × 12 annas,...	4,62,750
Gives total net income of, ...	18,30,880

or 11·59 per cent. on capital.

B.

Income from water rate on 6,17,000 acres at 2·5, ...	15,42,500
Miscellaneous dues 92 : 8 : : 15,42,500, ...	1,34,130
Gross revenue,... ...	16,76,630
Deduct maintenance at 10 annas per acre 6,17,000 at 10 annas, ...	3,85,625
Leaving a net return of, ...	12,91,005

or 8·17 per cent. on capital,

Adding for enhancement of land revenue at 12 annas per acre or 6,17,000 × 12 annas, ...	4,62,750
Gives total net income of... ...	17,53,755

or 11·10 per cent. on capital.

COMPLETE SCHEME.

Expenditure.

At the end of 17 years both schemes will be in full operation.

The capital on the 1st is, ...	2,25,25,521
Do. do. 2nd ,, ...	1,57,94,087
Making a total capital of, ...	3,83,19,608
The total cubic feet of water per second, ...	4,500
Acres of land irrigated at 250 acres per cubic feet, ...	11,25,000

Income.

A.

Income from water rate at Rs. 2·5 per acre 11,25,000 × 2·5, ...	28,12,500
Miscellaneous dues 92 : 8 :: 28,12,500, ...	2,44,565
Gross Revenue, ...	30,57,065
Deduct maintenance at 8 annas per acre 11,25,000 × 8 annas, ...	5,62,500
Leaving a net return of, ...	24,94,565

or 6·50 per cent. on capital.

Adding for enhancement of land revenue at 12 annas per acre 11,25,000 × 12 annas, ...	8,43,750
Gives total net income of, ...	33,38,315

or 8·71 per cent. on capital.

B.

Income on water rate at Rs. 2·5 per acre 11,25,000 × 2·5, ...	28,12,500
Miscellaneous dues 92 : 8 :: 28,12,500, ...	2,44,565
Gross revenue, ...	30,57,065
Deduct maintenance at 10 annas per acre 11,25,000 × 10 annas, ...	7,03,125
Leaving a net return of, ...	23,53,940

or 6·14 per cent. on capital.

Adding for enhancement of land revenue at 12 annas per acre 11,25,000 × 12 annas, ...	8,43,750
Gives total net income of, ...	31,97,690

or 8·34 per cent. on capital.

J. G. FORBES, *Capt., R. E.,*

Officiating Superintending Engineer, Sardah Canal.

Note to Appendix 2.

COMPARISON OF PRESENT WITH ORIGINAL ESTIMATE.

First portion of Scheme.

	Original estimate.	Present estimate.	Increase in present scheme.	Decrease in present scheme.
Head works at Bunbassa, ..	4,70,608	..	..	4,70,608
Supply channel, ..	4,94,844	4,94,844	..	..
Main canal, ..	66,27,498	55,39,632	..	10,87,866
Shahjehanpore branch, ..	9,76,620	9,76,620	..	..
Fyzabad branch to Unchá Kherá,	53,54,037	52,32,080	..	1,21,957
Lucknow branch, ..	18,96,071	18,96,071	..	..
Tramway, ..	7,39,110	18,00,000	10,60,890	..
Tools and Plant, ..	..	10,00,000	10,00,000	..
Total, ..	1,65,58,788	1,69,39,247	20,60,890	16,80,431
Establishment for accounts, ..	..	5,08,177	5,08,177	..
Grand Total, ..	1,65,58,788	1,74,47,424	25,69,067	16,80,431

Excess of present above original estimate, ... 8,88,636

Omitting the items in the present scheme which were not included in the original one, the total cost will be Rupees 1,48,78,357, (against Rupees 1,65,58,788, the cost of the original scheme); as follows :—

Excess of tramway,	... 10,60,890
Tools and Plant,	... 10,00,000
Establishment for accounts,	... 5,08,177
Total cost of additions,	... 25,69,067
Total of present scheme,	... 1,74,47,424
Present scheme less additions,	... 1,48,78,357

WHOLE SCHEME.

Ordinary discharge, ...	5,014 cubic feet.	
Possible do., ...	5,814 „	
Estimated cost of present scheme, ...		3,01,78,852

ADDITIONS IN PRESENT SCHEME.

Navigable canals, ...	7,47,993	
Tools and Plant, ...	10,00,000	
Addition to tramway, ...	10,60,890	
Phillibheet road, ...	30,000	
Establishment for accounts, ...	6,76,244	35,15,127
Cost of present scheme without additions, ...		2,66,63,725

or Rs. 5,317 per cubic foot of water entering the head, against Rs. 6,426 per cubic foot of water in the original scheme.

Taking the water which it is possible to send down the canal, for comparison, with the original scheme, we get :—

	Cost.	Possible discharge.	Cost per foot.
Present scheme, ...	Rs. 2,66,63,725	C. F. 5,814	Rs. 4,586
Original scheme, ...	„ 6,17,15,238	„ 10,780	„ 5,725

Even taking the cost of the present scheme with the additions above mentioned, or Rs. 3,01,78,852, the cost per cubic foot of water of ordinary discharge is, ... 6,018

The cost per cubic foot of water possible discharge is, ... 5,191

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